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INVESTIGATIONS WITH DDT IN CALIFORNIA, 1944

A preliminary report prepared under the direction of the

DIVISION OF ENTOMOLOGY AND PARASITOLOGY

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INTRODUCTION

This preliminary report has been prepared because of the current interest in DDT (dichloro-diphenyl-trichloroethane) as an insecticide. It will make available to other investigators the results of the past season's work. Though some of the studies here described have been rather extensive, none can be regarded as complete or final. At best they represent trends, and only further work can establish the desirability of using DDT to control the insects mentioned.

In 1944, after a lengthy and detailed symposium on the uses of DDT, the following statement appeared:[2]

New York, December 15.--The first official statement by the entomological profession on the new insecticide DDT was issued today by the American Association of Economic Entomologists, closing its 56th Annual Meeting.

Adopted by 392 delegates representing 1,000 members, it was offered both to summarize results of intensive research, revealed in the past day and a half of reports to the convention, and to correct "misunderstanding, over-optimism and distorted impressions." The statement follows:

"We feel that never in the history of entomology has a chemical been discovered that offers such promise to mankind for relief from his insect problems as DDT. There are limitations and qualifications, however.

"Subject to these, this promise covers three chief fields: public health, household comfort, and agriculture. As public health we include control of the insects which carry diseases that have scourged humanity, such as malaria, typhus, and yellow fever. Household comfort is taken to cover such things as flies, fleas, bedbugs and mosquitoes. Agriculture includes not only farms, gardens and orchards, but forests, livestock, and poultry.

"In the public health field DDT insecticides are so much more effective than previous weapons against malaria mosquitoes that for the first time there is a practical hope for eradicating that disease from this country. DDT proved in Italy that it is the first and only practical control for typhus. In the household field its amazing lasting effect promises relief for months from flies, mosquitoes and fleas. In the case of bedbugs, eradication from the American home has become a possibility.

"In agriculture, it is promising against a wide variety of destructive pests. These include most potato insects, many orchard and vineyard pests, numerous vegetable insects, as well as the chief insect enemies of vitally important seed crops. It appears to be effective against the pink bollworm and outstanding against the Japanese beetle, two of our worst imported pests. It promises also a more practical control of the pests which ravage thousands of square miles of forest, and against many of those which harass livestock.

"DDT will not kill all the important insect pests. It will kill many beneficial insects which are allies of mankind against the destructive species. Because of its toxicity to a wide variety of insects, its large-scale use might create problems which do not now exist. To illustrate, it is a superior insecticide for control of codling moths on apples, but in some sections at least will kill certain natural enemies and thus release other insects which may then become major problems.

"The research reports emphasize that we have not had time to develop entirely satisfactory mixtures and dosages of DDT insecticides, nor the methods and timing of application for many possible uses. Modern agricultural pest control often requires mixing several materials in combination treatments, and we know little of DDT's compatibility with many of these others. Researches thus far were made with material which was produced under pressure for military needs, and which is not necessarily the best form for agriculture.

"We do not know enough about effects on plants, animals, and soils. While most plants were not harmed by DDT insecticides in the experiments, injury to squash, corn, tomatoes and possibly fruit trees was reported. DDT is toxic to animal life when large amounts are taken internally or absorbed through the skin from oil solutions, but reports indicate a reasonable margin of safety. In the light of our present knowledge, heavy deposits on edible parts of plants should be avoided. Reports show definite toxicity to cold-blooded animal life including fish and frogs. There has not been time to learn the possible cumulative effects on soils. More and larger-scale experimentation is needed. Enough DDT for such research in 1945 should be provided."

There have been conflicting reports on the efficacy of the material against specific insects. Doubtless many of the discrepancies were caused by variations in the stock material, for there are various isomers of DDT with varying insecticidal potencies. Any two batches might well contain varying proportions of these isomers and thus differ in toxicity. In some early reports diluted dusts were erroneously regarded by the investigators as technically pure DDT powder, with the result that further dilution was made and produced innocuous products. Further, the forms in which DDT has been supplied have given rise to conflicting reports.

[1]Extensive work with DDT is being carried out at the Citrus Experiment Station at Riverside, but the results are not included in this report.

[2]From National Pest Control Association Service Letter no. 351. Appendix 1, page 1 (December, 1944).

There have also crept into the literature statements of "facts" that had originated as hypothetical suggestions, mere guesses to explain seemingly miraculous results. For instance, DDT dissolved in petroleum oil was said to produce a marked reduction in surface tension of the oil. This idea, which is without confirmation, was doubtless advanced as a tentative suggestion to explain the toxicity of small amounts of DDT in oil when applied to the water surface as a mosquito larvicide.

Already insecticide manufacturers are planning to produce dusts and sprays in which DDT has been incorporated. This material, when ready, will probably be largely in the form of proprietary products such as impregnated dusts, powders for spray, and emulsive oils. With these products, even when the content of DDT is known, the complicating factors introduced by the additional processing details and by the diluents, solvents, or adjuvants involved will necessitate caution in interpreting the results.

The material now being supplied to the armed forces is a micronized dust of technically pure DDT. This form is designed primarily for mixing with talc, pyrophyllite, or other diluent for use as a dry dust. The micronized powder can also be dissolved in diluents. Preferable for this purpose, however, is another product, much more granular and slightly moist, which is listed as "powder, dissolving."

Apparently this product is only slightly toxic to human beings. It is harmless to handle in the powdered form. In oily solutions, however, it may be absorbed through the skin; gross soiling should therefore be avoided. Absorption through the respiratory tract is apparently harmless; but, as a safety measure, men exposed to fogs or mists of the material should doubtless wear respirators or moistened gauze strips. According to experimentation with dogs, a dose that is toxic when administered by mouth ranges between 0.1 and 0.2 gram per kilo of body weight. This is many times the amount that could ordinarily be ingested in sprayed or dusted food or drink; these amounts would become important only in case of accidental ingestion through gross errors in food preparation or similar accidents.

DDT is apparently a true contact insecticide. There is some evidence that insects absorb it directly through the cuticula. It apparently has no repellent action whatever. An insect, after resting on it for a few moments, becomes highly irritable and makes every effort to leave. Soon a paresis of the limbs develops; then follows a complete paresis, including the wings; and, finally, death ensues. Because of the energy with which the insect at first attempts to get away, only a small percentage of the pests actually killed are found near by, provided means of escape are available. In treating a barn, one often finds more dead houseflies 25 to 30 yards away than inside the structure. In a house treated for flies or mosquitoes the greatest accumulation of dead pests often occurs near the windows, toward which the doomed insects attempt to fly.

DDT is insoluble in water. The following tabulation indicates its range of solubilities at normal temperatures with some of the common solvents:

Solvent	Grams per 100 cc
Cyclohexanone	100 to 120
Xylene	56
Ether	29
Diesel oil no. 2	10
Kerosene (crude)	5 to 8
Kerosene (purified)	2 to 4
Ethyl alcohol	1.5

DDT dissolves rather slowly in kerosene and diesel oil unless heated in a water or steam bath. The percentages mentioned above, however, will dissolve in a few hours at room temperatures, particularly if the material is agitated occasionally.

The following reports are compiled summaries of actual experiments carried on during 1944, except the section entitled "Use against Household Insects or Insects of Medical Importance."

Since enough DDT for field tests was not received until about May 1, early-season treatments against some insects were impossible. In the codling-moth investigation on pears, two lead arsenate calyx sprays had been applied before work with this chemical was initiated. In general, had it been known earlier that supplies of DDT would be secured, much of the investigational work could have been better planned and organized. A further complicating factor was the lack of data on residue tolerance or residue removal; this limited the size of plots and the amount of work done on certain of the fruit crops.

The DDT for these investigations was obtained from several sources. Because of the consequent variation in the product, an attempt has been made to distinguish the materials. Most of the experiments were conducted with DDT purchased from a single manufacturer. Of this firm's materials the following were used:

Description	Code
Commercial pure DDT	GNB-A
3 per cent DDT dust	A3
20 per cent DDT with wetting agent. .	A20
20 per cent DDT without wetting agent	AK20
5 per cent DDT in emulsive oil base .	SH5
20 per cent DDT in emulsive oil base.	SH20
20 per cent DDT in nonemulsive oil base	SHN20

If no code number is noted in the text, the material was donated by the Shell Oil Company or the California Spray Chemical Corporation, to whom we are indebted.

USE AGAINST HOUSEHOLD INSECTS OR INSECTS OF MEDICAL IMPORTANCE[3]

In order that this publication may serve a slightly wider field than that represented by the professional entomologists, a nontechnical summary of the uses of DDT against household insects or others of medical importance will now be given, with no claim whatever to originality or finality.

Interior Residual Spraying

One chief advantage in the use of DDT lies in its residual effectiveness for periods of even months after the initial application. This makes it an ideal insecticide for household use; a single treatment will sometimes suffice for complete control throughout a season. DDT has been employed with some success as a space spray, that is, a substitute for pyrethrum fly sprays: small amounts dissolved in purified kerosene are atomized in order to kill any insects present at the moment. This procedure is fairly satisfactory and, if the applications are frequent, eventually builds up a residue that will be effective against a reinfestation.

For a real residual treatment, one must deposit at least 100 milligrams per square foot. In most of the experimental work to date, 200 milligrams has been deposited per square foot; the recommendations below are made on this basis. There is evidence, however, that for practical purposes only half that amount is actually needed.

Kerosene Sprays

DDT may be dissolved in kerosene, up to 7 or 8 grams per 100 cc. For use with hand-sprayers a 5 per cent solution (about 2 pounds to 5 gallons) makes a very convenient mixture. In order to deposit 200 milligrams per square foot, which is considered an adequate residual application, the spraying should be so regulated that about 4 cc is applied per square foot. This is easily done on rough wood, papered surfaces, and composition boards; but on painted surfaces the material tends to run off. Enough is deposited with a hand-power sprayer with this dilution if the surface is barely moistened.

Water Emulsions

A satisfactory emulsion can be made by dissolving 3 pounds of DDT in 3 quarts of xylol to which has been added a satisfactory emulsifying agent. About 1 gallon of concentrate will be obtained. When this is diluted with 3 gallons of water, 2 cc of the emulsion per square foot will deposit approximately the required 200 milligrams. If power sprayers are used, it is probably advisable to add 6 gallons of water instead of 3 and to figure on depositing 4 cc of the emulsion per square foot instead of 2. Apparently the water emulsion produces a more effective deposit of chemical than the pure oil sprays. Unless the varnished surfaces on highly polished furniture are covered during the spraying, spotting from the xylol may result.

Spraying Suggestions

The ordinary cylindrical sprayer of 3-gallon capacity is very effective, provided the cover can be screwed down tightly; preferably, the sprayer should have tight-fitting neoprene (oil-resistant) gaskets and tightening lugs that fit under the rim. Helpful accessories are 2 or 3 feet of additional hose length, and a stick that is easily attached to the spray wand to lift the nozzle to high places in the room. For general spraying, the ordinary circular disc nozzle with an aperture in the center is satisfactory. The aperture should be one that produces a medium spray, since either coarse or atomized sprays are very wasteful of material. With the nozzle properly adjusted, a spraying distance of 6 to 8 inches from the surface to be treated gives excellent results and keeps the spray well under control.

Hand sprayers have proved more practical and economical than power sprayers except in buildings with high roofs or ceilings. For ordinary rooms, whose surfaces can all be reached from the floor, the hand-sprayer is far more effective: the material can be concentrated in a set spray without atomization, and no extra man is needed to manage the engine and hose line.

Control of Mosquito Larvae

For the control of mosquito larvae DDT as a dust is no more useful than paris green. At present, with a price differential of well over 50 cents a pound, it would seem inadvisable even to experiment with DDT as a dust larvicide. The chief value of the spray is that extremely small quantities may be as effective as the application of large amounts of fuel oil. A 5 per cent dilution in kerosene or diesel oil is excellent. The ideal treatment recommended for this dilution is 1 to 2 quarts per acre, as contrasted with 18 to 20 gallons of fuel-oil dispersal. These figures give some idea of the minute quantity that should be used.

Contrary to reports from some of the earlier experiments, however, DDT has no magic power of spreading itself over water surfaces. In dispersing the small amount of material required, one must make sure that it is introduced over the entire surface, particularly if rafts and booms of floatage will cut its access to the sheltered areas where breeding may be intense. In dispersing the 5 per cent kerosene mixture, one may well apply the material from the windward side and allow it to drift over the breeding area. In order to increase the coverage and to cut down the care which is necessary in applying minute amounts with kerosene as a carrier, considerable work has been done with emulsions.

[3]Prepared by S. B. Freeborn, Professor of Entomology, Assistant Dean of the College of Agriculture, and Assistant Director of the Agricultural Experiment Station.

By using a quick-breaking emulsion, such as is made with phthalic glyceryl alkyd resin, one can apply the material on the acre basis, figuring at the rate of about 1/10 pound of DDT per acre. If, however, a tight emulsion is produced, as with polyethylene emulsifier, the dosage should be figured roughly on a volumetric basis so that the DDT will not exceed 1 part in 10 million. Any greater concentration will certainly be detrimental to fish. The addition of DDT to irrigation water at its source has proved particularly disappointing.

Control of Adult Mosquitoes

A residual spray applied at the rate of 100 to 200 milligrams per square foot will effectively kill all adult mosquitoes that come to rest on the treated walls, for a period of at least 3 months and possibly longer.

Control of Houseflies and Stable Flies

Apply DDT exactly as for residual spraying for mosquitoes. The spraying of manure piles, the walls behind them, and the most obvious gathering places in the stables will destroy numerous flies before they leave the breeding grounds. For household control treat especially screens, door and window frames, shelves, the edges of pillars, and other areas that fly "specks" indicate as habitual resting places.

Control of Fleas

A 10 per cent DDT dust in talc or pyrophyllite rubbed into the fur of pets constitutes a very satisfactory primary source of control. A 5 per cent kerosene spray applied to floors, chicken houses and yards, dog kennels, and stable floors is extremely effective. Persons allergic to flea bites have gained considerable relief by treating the underclothes with a 10 per cent DDT dust in talc.

Control of Roaches

All the common household roaches except the German roaches are easily controlled. Either a 10 per cent DDT dust used along the areas generally traversed by roaches or a kerosene spray containing 5 per cent of DDT heavily applied is the most effective means of control. A 25 per cent dust or repeated applications of the 5 per cent kerosene spray will eventually make some inroads on the German roach. For practical purposes, however, there is little to be gained by substituting DDT preparations for the orthodox treatment with sodium fluoride, particularly for the German roach.

Control of Bedbugs

A kerosene spray containing 5 per cent of DDT is remarkably effective against bedbugs. Mattresses, pillows, springs, and bedframes should be lightly sprayed so that the surface is barely moistened. If the beds are placed upright against the wall, the spraying of this furniture incidentally treats the wall behind the bed. A cursory spraying along the baseboards facilitates the control; but even if only the beds and bedding are treated, the bugs in nocturnal search for food will encounter enough poison to kill them eventually. The advantage of this treatment as contrasted with fumigation is that reinfestations are eliminated for several months, whereas fumigation kills only the bugs present at the moment.

Control of Body Lice

A 10 per cent DDT dust in talc, applied to the inside of the clothing at the rate of about 1 1/2 ounces per individual, will adequately control body lice.

Control of Argentine Ants

A kerosene spray containing 5 per cent of DDT is extremely toxic to Argentine ants and has been successfully used around the casings of doors and windows of masonry buildings. The ordinary frame house, however, provides many entrances for this insect; under these conditions, standard Argentine ant poisons placed around the outside of the house are far more effective than an attempt to treat all of the interior.

CONTROL OF LYGUS BUGS ON ALFALFA SEED CROP WITH DDT[4]

Lygus bugs are among the most serious pests attacking alfalfa seed crops. In heavy infestations they make crops unprofitable or cause complete seed failures. Thus far no satisfactory chemical control has been developed. According to observations in the northwestern portion of the San Joaquin Valley, the bugs are likely to reach a serious economic level when an average of 5 individuals are taken to a sweep of a standard insect net. A discussion of the relation of lygus bug populations to alfalfa seed production in California is now being prepared.

The experiment with DDT described here was conducted in a 38-acre alfalfa field about 2 miles east of Tracy. When this field came to our attention it had been producing blooms for a short period. The lygus population was so large that a satisfactory seed crop evidently could not be produced. The predominant species was *Lygus hesperus* Knight, and there were a very few specimens of *L. elisus* Van D. A 2-acre plot was set out in a heavily infested portion of the field. One large plot rather than several smaller replicated plots was used in order to reduce to a minimum the hazard from migrating insects. In previous studies, small plots had proved undesirable because the adult lygus fly about so freely.

[4]Prepared by A. E. Michelbacher, Assistant Entomologist in the Experiment Station; Ray F. Smith, Principal Laboratory Technician, Division of Entomology and Parasitology; and Gordon L. Smith, Associate in the Experiment Station.

In determining populations, collections were made at 18 to 30 stations within the plot, and from 30 stations surrounding the plot area.

On July 25, the day before the first dust application, an average of 14.6 bugs were collected to a sweep of an insect net in the experimental area. This is considered to be the initial population.

A 3 per cent DDT dust (A3), with pyrophyllite as a carrier, was applied at the rate of approximately 28 pounds per acre. The duster was a self-mixing machine with a 3 × 8 inch fan powered by an 8-horsepower Le Roi water-cooled engine. The normal fan speed was 3,000 to 4,000 r.p.m., and the nozzle used directed the dust downward. A 25-foot strip could be dusted by rapidly moving the single nozzle back and forth while the duster was being towed.

The work was done under favorable conditions. The experimental area was first surveyed on July 28 (2 days after the dust was applied). The lygus population was greatly reduced in the dusted plot as compared with the surrounding area. Although the effect of the poison on other insects could not easily be measured, lepidopterous caterpillars present appeared to have been killed. Bees were abundant and were not perceptibly injured. A heavy infestation of the differential grasshopper, Melanoplus differentialis (Thomas), did not appear to be affected.

Additional population surveys on August 2 and August 9 showed an increase in lygus within the plot, but only proportional to that which occurred in the undusted area. The ratio of adults to nymphs, however, was much greater in the dusted than in the nondusted check, perhaps because the nymphs are more easily killed by DDT than are the adults, or because the plot was reinfested by adults that flew in. Possibly both factors entered into the population changes. Judging from the following observations, however, the very young nymphs were more easily killed than the older forms. On August 2 only late-instar nymphs and adults were collected within the plot, whereas in the check, lygus bugs of all stages of development were taken. Not until the August 9 survey did any very young nymphs appear in parts of the dusted plot. At this time the prospects of obtaining a satisfactory seed crop looked better in the dusted than in the undusted area. The total bug population per sweep, however, had risen to 10.46. Although this was small as compared with 48.7, the average number collected in the undusted area, it was considered large enough to interfere greatly with seed production. The plot was therefore dusted again on August 12, the material, rate, and means of application being the same as in the July 26 treatment. Conditions were favorable for the work, and many adult lygus flew up as the dust was being applied.

A survey 4 days later on August 16 showed a marked drop in the populations; again, nearly all the nymphs observed were large, a fact suggesting, as before, that the very immature forms are the ones more susceptible to DDT. The dusted area showed much more bloom than the check. Over most of the latter the buds were being blasted by lygus. As a result, the dusted area stood out from the rest of the field as a faint purple patch. Considerable seed was setting. On August 22 a survey revealed that the lygus population was still rather small in the treated plot, but that the population in the check area was falling off rather rapidly. Later surveys showed a slight rise in the population in the plot area; but the population outside continued to fall, so that the two tended to become equal. As the effect of DDT became less, lygus bugs apparently found conditions in the dusted plot more favorable than outside, perhaps because of the more abundant bloom; at least, in some of the later surveys the highest counts were associated with extra-heavy bloom.

The information obtained in the surveys is summarized in table 1; and the lygus bug popula-

TABLE 1

Lygus Bug Population Trends in Undusted Area, and in Area Dusted with DDT on July 26 and August 12, 1944

Date of survey	Average number of lygus bugs per sweep						Per cent reduction in total population
	Check area			Dusted area			
	Adults	Nymphs	Adults and nymphs	Adults	Nymphs	Adults and nymphs	
July 25	4.1	10.5	14.6	4.10	10.50	14.60	0.0
July 28	4.3	16.3	20.6	0.73	1.32	2.05	90.0
August 2	5.5	19.3	24.9	2.37	1.43	3.80	84.7
August 9	11.2	37.5	48.7	4.78	5.68	10.46	79.3
August 16	16.6	22.2	38.8	1.25	3.22	4.47	88.5
August 22	16.1	12.9	29.0	3.40	0.35	3.75	87.2
August 29	11.4	4.6	16.0	5.13	0.21	5.34	66.7
September 8	6.0	7.2	13.2	4.08	2.76	6.85	49.2
September 21	2.6	8.0	10.6	2.11	4.83	6.95	34.4

tion trends, both inside and outside the dusted area, are plotted in figure 1. For the nondusted area this trend appears to be of the

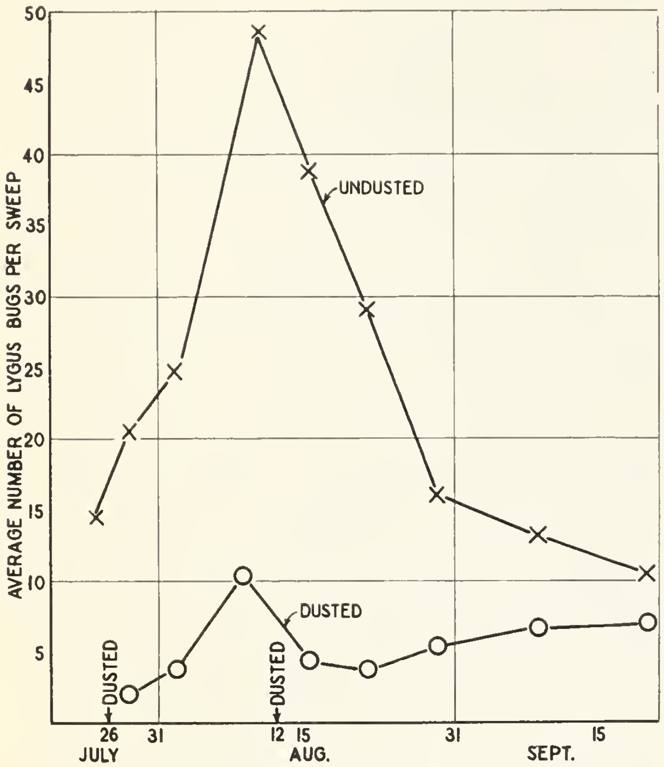

Fig. 1.--Lygus-bug population trends for dusted and undusted plot in an alfalfa seed field.

normal type that occurs in alfalfa fields during the growth of a seed crop. The rapid fall in the population may sometimes, though not always, result from the drying up of the seed field. There is also some possibility that parasites and predators may aid in reducing the population. Because of the high water table in the field where the plot was located, the alfalfa continued to put out new growth. There was, therefore, considerable vegetation that should have been favorable to the lygus bugs. Since there was, notwithstanding, a rapid decline in the population, the role of natural enemies may be regarded as a possible factor.

The last survey was made on September 21. At this time much seed had been set in the dusted plot. The setting seed had caused the tips of the alfalfa to bend over and in some places had caused the alfalfa to lodge. As it became impossible to make sweeps inside and outside the plot that would be comparable, further surveys were omitted.

An analysis of the alfalfa, 25 days after the second application, showed a residue of 29 parts per million of DDT, as reported in the concluding section of this paper.

The seed crop was not cut until October 20 to 27. Between September 15 and this time, some seed was set in the undusted area. In spots it was rather marked, and was undoubtedly associated with the decided falling off of the lygus population. The seed in the dusted plot was ready to harvest by October 1; but the farmer delayed harvest in order to obtain the maximum yield from the nondusted area. Shortly after October 27, however, a number of heavy rains caused the cut seed to germinate or rot in the field. The yield, therefore, could only be estimated. Apparently the nondusted area would not have produced more than 150 pounds of clean seed, while the dusted area would have yielded at least 400 pounds per acre.

Conclusions

On the basis of the experiment, a 3 per cent DDT dust appears to be very effective in controlling lygus bugs on alfalfa seed. The results are so promising that further and more extensive work is strongly recommended. In this particular study a 2-acre plot was treated in a 38-acre field. For satisfactory control, two dustings appeared necessary. If, however, the entire field had been dusted, one treatment would probably have sufficed. This certainly is true if the second dusting in our investigation was rendered necessary by large migrations of adult bugs from the undusted to the dusted area. The following points need further study: (1) methods of application, (2) timing of application, (3) rate of application, (4) concentration of material to use, (5) effect of the DDT dust on other insects, and (6) natural factors affecting the control of lygus populations.

Although extremely promising, the use of DDT for controlling lygus bugs on alfalfa seed crops should not be recommended until further investigations substantiate the results of this season's study.

THE USE OF DDT ON ALMOND TREES[5]

At Escalon, three almond trees were sprayed on June 26 with the following mixture of DDT:

20 per cent DDT powder (AK20) . . .	5 pounds
Blood albumin	4 ounces
Water	100 gallons

The DDT and blood albumin were thoroughly mixed, then slurried, and added to a spray tank that was half full of water.

The spray was applied to determine what effect DDT has upon the shot-hole borer, Scolytus rugulosus (Ratz.). Although no definite information on this point was obtained, other observations of interest were noted. A heavy infestation of mites (the brown almond mite and the two-spotted mite) built up in the three trees that were sprayed, which soon evidenced severe injury. As the season progressed, the trees immediately

[5]Prepared by Clark H. Swanson, Assistant in Agricultural Extension; and A. E. Michelbacher, Assistant Entomologist in the Experiment Station.

adjacent to the DDT trees showed an increase in the mite population--unquestionably because of a migration from the three sprayed trees. The sprayed trees finally suffered complete defoliation, while those in the main portion of the orchard retained their leaves.

Although very limited, this experiment would indicate that DDT should be used on almonds with a great deal of caution.

TESTS WITH DDT ON LARVAE OF FRUIT TREE LEAF ROLLER AND TUSSOCK MOTH, ATTACKING APPLE[6]

Apple trees in Santa Clara County infested with nearly mature larvae of the fruit tree leaf roller, Archips argyrospila (Wlk.) and with immature larvae of the tussock moth, Hemerocampa vetusta Bdv., were treated May 1, 1944, with a spray containing 2.5 quarts of 20 per cent DDT in oil, with emulsifier (SH20), per 100 gallons of water. Within a short interval after spraying, both species of larvae left the foliage and were hanging by their silken threads. Many dropped to the ground; and none were found on the trees 48 hours after spraying, whereas unsprayed trees remained infested. The spray caused a spotted leaf injury.

LABORATORY TESTS WITH TWO BERRY INSECTS[7]

DDT was tested in the laboratory as a spray and as a dust on the strawberry rootworm, Paria canella (Fab.), and on Fuller rose weevil, Pantomorus godmani (Crotch). A water-suspension spray of 4 pounds of 20 per cent DDT powder with wetting agent (A20) per 100 gallons of water was poured on a glass plate. The plate was placed in a vertical position so that excess spray could run off. A white film was visible on the plate when dry. Then, 291 days later, the insects mentioned above were caged on this residue with clean strawberry leaves. After 4 days, all were on their backs; and after 5 days, all were dead.

DDT was similarly tested as a 3 per cent dust (A3) by applying a thin deposit of dust on a glass plate, then immediately caging the insects on it with clean strawberry leaves. All were dead at the end of 5 days, and the speed of killing was no greater than that of the aged spray deposit described above.

[6]Prepared by A. D. Borden, Associate Entomologist in the Experiment Station; and L. R. Jeppson, Associate in the Experiment Station.

[7]Prepared by Leslie M. Smith, Associate Entomologist in the Experiment Station.

CONTROL OF CERTAIN COTTON INSECTS WITH DDT[8]

Tests on cotton insects were made on four plots of cotton at the United States Department of Agriculture Field Station, Shafter, California. Each consisted of 4 rows 150 feet long, dusted with 3 per cent DDT dust (A3) at the rate of 25 to 30 pounds per acre, applied with a Root rotary hand-operated duster. The first application was made on May 18 at 7 p.m., and the second July 18 at 5 a.m.

Cotton plants 5 to 6 inches tall that were injured by onion thrips, Thrips tabaci Lind., and by western flower thrips, Frankliniella occidentalis (Perg.), were selected for making a test with DDT to control these insects. There were also spotted infestations of cotton aphids and red spiders, Tetranychus atlanticus McG. An average of 2 adult thrips per plant was found by snapping the tops of the plants against a dark-colored card. There was also an average of 1 cotton fleahopper, Psallus seriatus (Reut.), nymph to each 5 plants.

In 24 hours after the dust was applied, the 4 check plots of undusted plants showed no change in the number of thrips and fleahoppers present. On the dusted plants, these pests could not be found; but there was no apparent control of aphids and red spiders.

The characteristic injury done to a cotton plant by the species of thrips involved is the killing of a terminal bud; the result is a bushy plant, which produces a crop later than a normal plant. If the growing season is long and favorable, the quantity of fiber from these bushy plants may equal that for normal plants. In November, a count of the bushy and erect plants showed an average of 21.2 per cent bushy plants in the dusted and 20.2 per cent in the untreated plots. These figures are based on counts of about 1,800 plants from each plot. The damage had evidently been done before the dust was applied, for shortly after the treatment on May 18, the growth of all plants was rapid, and no further injury of this type occurred.

The same plots were dusted again on July 18 for control of the western plant bug or cotton dauber, Lygus hesperus Knight. Before application populations were determined by shaking tops into an insect net early in the morning. There were no nymphs; and the adult population was very low, averaging only 4 insects to each 25 tops. There were so few aphids, red spiders, and other insect pests present that none of these were considered.

After the treatment, some observations were made of insect activity on the dusted plants. Many insects alighted on these plants; there was no evidence of the dusts' being repellent. Honeybees usually flew directly to freshly opened flowers and therefore usually did not alight on

[8]Prepared by Gordon L. Smith, Associate in the Experiment Station.

dusted surfaces; the few bees that did crawl over the bracts and corolla into the flower showed little or no apparent effect of the insecticide. Lygus hesperus would alight on the dusted surfaces, but moved about and did not feed; after a few seconds the action of the hind legs became abnormal but the insect was able to fly 40 or 50 feet. Two predaceous insects, Geocoris pallens Stål and Nabis ferus (Linn.), behaved in much the same manner.

In 24 hours, samples were taken again as on the preceding day, at an hour when it was too cool for much flight of plant bugs to occur. There were no Lygus hesperus collected on the dusted plants, and no Nabis ferus; but there were a few Geocoris pallens.

The seed cotton from these plots was harvested the last of November. The total yield from the four treated plots was 492 pounds, whereas that from the four check plots was 487.

The 1 per cent increase in the total yield from the dusted plots over the checks is too small to be significant. The infestation of lygus bugs was very slight, and no other injurious species were of importance on cotton in the San Joaquin Valley during 1944.

Insects often found on cotton but swept from alfalfa were lightly dusted with 3 per cent DDT dust and held in the insect net with alfalfa cuttings over night. By this method complete kills were obtained of all lygus bugs, onion thrips, western flower thrips, and a leafhopper of the genus Empoasca. There were only 4 specimens of Diabrotica 11-punctata Mann., and they were killed. There were both living and dead bean thrips, Hercothrips fasciatus (Perg.) in the nets. About 50 per cent of the yellow-striped army worms (Prodenia praefica Grote) were shriveled; when these were placed on fresh alfalfa cuttings and observed for 24 hours, none of them fed. The 3 per cent dust gave no indication of being toxic to the Pentatomids, Chlorochroa sayi Stål and Thyanta custator (Fab.), and the differential grasshopper, swept from alfalfa.

CONTROL OF FLIES IN A DAIRY BARN WITH DDT[9]

The dairy barn used in this experiment was located at Patterson. Flies long had been troublesome, and the commercial sprays being used were not giving satisfactory control. The barn was of cement construction with a corrugated iron roof. The ceilings of the storeroom, washroom, milk room, and passageway were finished off with cement. The barn was built to accommodate 24 cows at a time, and its entire floor space was 1,826 square feet.

The barn was first examined on July 7 just before the afternoon milking. Flies were swarming throughout the structure. Even in the milk-cooling room they were abundant. At this time the milk-cooling room and the washroom were treated with a 4 per cent DDT spray in light oil. This mixture was composed of 1 part by volume of 20 per cent DDT in nonemulsible oil base (SHN20) to 4 parts of solvent. All movable equipment was first taken away, and the milk cooler and the sinks were covered with heavy paper to protect them. The chemical was then applied with a hand atomizer from which the nozzle had been removed. The entire surfaces of the walls and ceiling were wet with a coarse spray. About 3/4 gallon was used.

The control obtained was good; but, apparently, better results could be expected if the entire structure were treated. All flies that gained entrance into the washroom and the milk room were killed; but since there was no control in the rest of the barn, more flies than desirable continued to enter these rooms.

On August 2 the control in the washroom and the milk room was still very good, but on this date the entire barn was sprayed. All foodstuffs were removed from the milk barn; the floor and the feed troughs were hosed clean. The milk room and the washroom were then sprayed with the same material and in the same manner as on July 7. The same precautions were followed. About 1 gallon of the 4 per cent spray was used in covering the walls and ceiling.

The following spray mixture was applied in the passageway and the milk barn:

20 per cent DDT powder (AK20)	10 pounds
Blood albumin	6 ounces
Water	100 gallons

This mixture was applied with a Bean sprayer at a pressure of about 500 pounds through a Meyer spray gun. All inside surfaces of the milk barn and passageway were treated, as well as the entire outside surface of the structure except the corrugated roof. Just before the inside of the barn was sprayed, the feed troughs were thoroughly hosed off to wet them. Immediately after the spraying, hosing was repeated in order to wash off the spray residue that had dripped or otherwise drained into the feed troughs. About 85 gallons of the dilute spray was used to treat the entire structure.

The control resulting was very good. In the mornings no live flies could be observed until 10 o'clock or later, and it was not necessary to strain the milk. During the afternoon milking some flies entered the barn, but by morning all were dead. The washroom and milk room remained almost free of flies, even in the afternoon. Not until August 25 was there any evidence of a reduction in the control. At this time some few live flies were observed on the walls of the milk barn in the mornings. As late as September 15 most of the flies that entered were dead by morning, and only a few dozen live ones could be

[9]Prepared by A. E. Michelbacher, Assistant Entomologist in the Experiment Station; Ray F. Smith, Principal Laboratory Technician, Division of Entomology and Parasitology; and Gordon L. Smith, Associate in the Experiment Station.

found in isolated spots on the walls. In the afternoons many flies were present. By September 21 the spray was still somewhat effective, but in the mornings many of the flies that dropped during the night were still partly alive. The loss in effectiveness, slow at first, was becoming much more noticeable; by the end of September some supplemental spraying had to be done on warm days. This was not necessary when the weather was cool. Control was no longer effective, although flies were still being killed as late as October 16, ten weeks after spraying. In the washroom and milk room excellent control was obtained; even at this time there was no apparent tapering off in the effectiveness of the treatment.

On October 16, however, the entire structure was again sprayed, with the same precautions as on August 2. The spray used on the outside of the barn, interior of the milk barn, and passageway was as follows:

20 per cent DDT wettable powder. . .	10 pounds
Light miscible oil	1/2 gallon
Water	100 gallons

The DDT was slowly added when the spray tank was 1/2 full, and the oil was added when the tank was 2/3 full. From 70 to 75 gallons of the spray mixture was applied to the barn. The washroom and the milk-cooling room were sprayed with a 13 per cent solution of DDT in oil, diluted with water at the rate of 1 to 50 (6 level tablespoonfuls of the 13 per cent DDT solution to a gallon of water). About 2 gallons of the dilute solution was used, applied with a 2-1/2 gallon compressed-air pressure sprayer.

The experiment is still in progress, and excellent control has continued; the barn was last examined on November 14 at 3 p.m. In the entire structure only 2 or 3 flies were found.

Conclusions

As used in this experiment, DDT resulted in excellent control of flies. With careful application, there appears to be little hazard to man and animals. The material should find wide use in dairies. Further investigations are necessary, however, before the practice can be recommended. In the present study a water suspension has been largely used; but further work with DDT in kerosene or a light spray type of oil is desirable.

Experiments are now being planned to compare water suspensions of DDT with DDT-kerosene mixtures. The problem of determining the most satisfactory concentration of DDT to use in sprays will also be investigated, and the best means of application will be sought.

EXPERIMENTS WITH DDT AGAINST THE GRAPE LEAFHOPPER[10]

The grape leafhopper, *Erythroneura elegantula* Osb.,[11] is an important pest of grapes in the San Joaquin Valley. An investigation on the use of DDT as a possible method of control is here reported.

Methods

Applications made on May 5, 1944, in a vineyard near Woodlake, Tulare County, were made on 3 varieties of table grapes (*Vitis vinifera*)--namely Ribier, Red Malaga, and Emperor. The treatments were as follows:

Vapo-sprays: DDT in a vapo-spray base oil,[12] applied at the rate of 1.75 gallons per acre. The application was made to one side of every row, with a machine constructed by the ranch owner and operated by experienced ranch employees.

Applications were as follows: 1.2 per cent DDT vapo-spray was applied to 15 rows of Emperor grapes late in the morning; a 0.6 per cent vapo-spray was applied to similar numbers and at the same time of day, to Red Malaga grapes; and a 0.6 per cent vapo-spray was applied in the early afternoon to 13 rows of Ribier grapes.

Dry-mix dusts: 50 per cent commercial dusting sulfur with DDT[13] and Frianite diluent to make 100 per cent by weight. These dusts were used at three concentrations, namely 1, 3, and 5 per cent DDT. The sulfur duster used was owned and operated by an experienced commercial worker. Treatment was made in the same manner as a normal application of sulfur for mildew control. The duster traversed every other middle. The rate of application was 20 pounds per acre and the three dust mixtures were applied each to 13 rows of Ribier grapes in the early afternoon. The grape shoots were 2 to 3 feet long; the foliage somewhat heavier on Emperor and Red Malaga than on Ribier.

Pre-treatment and post-treatment counts were made on May 5 and May 9 respectively. Since the hatch of first-brood nymphs had not started in this vineyard, only the overwintering adults were counted. Samples were taken by treating individual vines with a hand-operated fly-spray atomizer containing pyrethrum in oil, after

[10] Prepared by Norman W. Frazier, Junior Entomologist in the Experiment Station; and E. M. Stafford, Junior Entomologist in the Experiment Station.

[11] Determined by R. H. Beamer, University of Kansas, Lawrence, Kansas. This is the predominant and most damaging species on grape in the San Joaquin Valley. In literature concerning this species in this region it has erroneously been referred to as *Erythroneura comes* (Say), a species that occurs east of the Rocky Mountains.

[12] Ten per cent of a light summer oil of 60 per cent viscosity (92 U.R.) and 90 per cent kerosene.

[13] DDT stock for making these dusts was 20 per cent DDT without wetting agent (AK20).

spreading a canvas under the vine. The vines were shaken, and the fallen leafhoppers were counted on the canvas. Counts were made under 6 vines for each treatment on Emperor and Red Malaga, and under 4 vines for each treatment on Ribier.

On May 15, counts were made of live and dead nymphs in 25-leaf samples for each treatment; on May 23, in 10-leaf samples. Samples were taken by picking the requisite number of basal leaves (where nymphal populations were highest) at random, 1 leaf from a vine, all vines in a single row. The leaves from each row were collected in a paper bag, and the nymphs counted under a binocular microscope. The live nymphs remained in an undisturbed state until exposed for a time to the light near the microscope.

Population samples of nymphs and adults were taken on June 13 by picking 100 leaves per treatment into paper bags and killing the insects with HCN. Basal leaves (where populations were highest) were selected at random, 1 leaf per vine from vines in all the rows where previous samples had been taken. The leaves were removed from bags, and the dead leafhoppers brushed to a pane of glass and counted.

A final population sample of nymphs and adults was taken on September 1, 2, and 3. The same method was used as on June 13 except that the samples had to be taken during a short period before sunrise, when the leaves could be gathered without too greatly disturbing the adults. A total of 50 leaves were picked per treatment, 1 leaf per vine, in the same rows from which previous samples had been taken.

Checks consisted of adjoining vines in the same blocks of Emperor and Red Malaga that had been treated on May 1 with a proprietary vapo-dust oil containing pyrethrins, applied at the rate of 1.75 gallons per acre. Because of this treatment no samples were taken from these vines on May 5.

Results

Table 2 gives the results. Evidently the greatest reduction of adults up to the fourth day after treatment occurred in the vapo-spray applications of 1.2 per cent DDT on Emperor and 0.6 per cent DDT on Ribier. The good but lower re-

TABLE 2

Experiments with DDT for Controlling the Grape Leafhopper at Woodlake, on Plots of About Three Acres Each

Grape variety and treatment	Average number of adults per vine		Per cent reduction from pre-treatment counts	Per cent dead nymphs		Average number of leafhoppers (nymphs and adults) per leaf		Relative leafhopper damage to vines October 15
	Pre-treatment counts, May 5	Post-treatment counts, May 9		Per 25 leaves, May 15	Per 10 leaves, May 23	June 13	September 2*	
Vapo-sprays								
Emperor								
1.2 per cent DDT	69.2	1.1	98.3	4.5	55.0	0.07	12.84	Moderate
Oil-pyrethrum†	....	12.8	....	0.0	3.8	1.32	19.66	Moderately severe
Red Malaga								
0.6 per cent DDT	75.5	8.2	89.1	2.3	9.5	1.07	1.62	Slight
Oil-pyrethrum†	....	23.8	....	0.0	0.0	2.01	.....‡	Slight
Ribier								
0.6 per cent DDT	64.7	0.66	98.9	59.1	67.3	0.84	10.16	Moderate
Dusts								
Ribier								
5 per cent DDT	50.0	6.3	87.5	83.7	93.8	0.66	10.56	Moderate
3 per cent DDT	50.7	18.3	64.0	94.8	73.9	0.76	27.66	Severe
1 per cent DDT	35.0	32.5	7.1	18.5	17.3	3.39	.....§	Very severe

*The approximate ratios of nymphs to adults were 1 to 5.5 and 1 to 3, respectively, for the DDT and oil-pyrethrum vapo-spray treatments on Emperor as compared with a 1 to 1 ratio in the 0.6 per cent DDT vapo-spray, the 5 per cent, and the 3 per cent DDT dust treatments on Ribier.

†A proprietary vapo-spray oil containing 3 per cent of a 20 to 1 pyrethrum extract (2 per cent pyrethrins).

‡This block treated with insecticide June 17 and rendered valueless for further use as a check.

§Many leafhoppers killed by drift of gas from an adjoining vineyard treated with Cyanogas the night before the sample was to be taken; population estimated to be more than 3 times greater than present in the Ribier block that received the 3 per cent DDT dust treatment.

duction secured with the 0.6 per cent DDT vapo-spray on Red Malaga might possibly be explained by the denser foliage as compared with Ribier. Then, too, the position of Red Malaga leaves tends to be vertical, thus partially preventing effective coverage of the under surface, whereas Ribier leaves tend to be horizontal and allow somewhat better coverage. Treating vines from one side only and using a low dosage may have increased this natural difference in coverage. The dry-dust mixtures on Ribier were less effective against the adults than the 0.6 per cent DDT vapo-spray.

On May 15 the persistent toxicity of both the 5 per cent and 3 per cent DDT dry-dust mixtures to nymphs appeared more effective than any of the 3 vapo-spray treatments. On May 23, however, the 3 per cent and 1 per cent dry-dust treatments showed decreasing effectiveness as compared with the May 15 samples, whereas all the remaining treatments indicated a continuing or increasing effectiveness.

On June 13 the population consisted of very few remaining overwintering adults, an appreciable number of newly matured first-brood adults, and a much larger number of first-brood nymphs. Very few adults had yet moved between blocks or into treated plots. Apparently the population within a given treatment area was composed largely of first-brood nymphs and adults that had hatched from eggs within that area. Judging from the population sample on that date, the 1.2 per cent DDT vapo-spray had more effectively reduced and held the population to a low level than had any other treatment. The 5 per cent and 3 per cent dry-mix dusts and the 0.6 per cent vapo-spray treatments on Ribier grapes showed moderate control, with relatively small differences between the treatments. The relative effectiveness was in the order mentioned. The effectiveness of the 1 per cent dry dust apparently was very low, and the population in this treatment might well serve as a check for the other 3 treatments on Ribier.

By September 2, when the final population samples were taken, the DDT had lost much, if not all, of its persistent toxicity to the grape leafhoppers. This fact is indicated by the greatly increased populations recorded in table 2. Populations on this date were composed of nymphs and adults hatched within the treatment area, as well as adults that had migrated in. Differences were still apparent among the treatments, and relative effectiveness was much the same as evidenced on June 13. There were still fewer nymphs in the Emperor block treated with 1.2 per cent DDT vapo-spray than in the Emperor block treated with oil-pyrethrum or in the Ribier treatments, as is indicated by a footnote to table 2. The high ratio of adults to nymphs in the Emperor block, as compared with the Ribier treatments, might be explained by the fact that in years past there has always been a heavy movement of adults into the Emperor block during late summer. The Red Malaga vines in September had been harvested and were matured, relatively nonsucculent, and apparently less favorable to the leafhoppers than the other varieties that were irrigated later and kept in a more succulent condition of growth. This fact probably explains the relatively low leafhopper population present on September 2.

The October 15 survey of the relative accumulated leafhopper damage in the various treatments is contained in the last column of table 2.

Conclusion

In these trials, DDT applied either as vapo-spray or as a dry dust mixed with sulfur appeared to be effective against the grape leafhopper adults and the nymphs. Toxicity to nymphs persisted at least 22 days. The effect of treatment was noticed 4 months after application. A more refined technique of application, together with adjustment of dosages and concentration, would undoubtedly yield better results than those obtained. DDT appears to hold considerable promise as means of controlling the grape leafhopper. More experiments are necessary, however, before recommendations can be made for commercial use.

TESTS WITH DDT AND OTHER INSECTICIDES FOR CONTROLLING ONION THRIPS IN THE SAN JOAQUIN DELTA[14]

Spray and dust applications with several insecticides for the control of the onion thrips, *Thrips tabaci* Lind., were made May 24 on McDonald Island near Stockton on a field of green onions, using knapsack sprayer and rotary hand-duster. Plots were 5 feet wide and 30 feet long. A strip 5 feet wide was left untreated between the plots. The thrips population was sampled by counting the adults and nymphs from 10 plants in each plot 2 and 8 days after treatment. Table 3 gives the results.

In these tests DDT, applied either as a spray or dust, was apparently more effective in reducing and preventing the increase of the onion thrips population than was a rotenone or dinitro spray.

In an adjoining young-onion field on June 1, dusts containing DDT were applied at the rate of about 50 pounds per acre by means of a rotary hand-duster to plots 25 by 50 feet. Population counts of adults were made 1 and 14 days after treatment, and of nymphs 1, 14, and 21 days after treatment. For each survey the thrips were counted on 20 plants selected at random in each plot. Table 4 gives the results.

According to these data, the 3 per cent DDT dust checked the increase of thrips for a longer period than the 1 per cent DDT dust, and the 1 per cent dust prepared with methyl naphthalenes was more persistent in its effects on the thrips

[14]Prepared by L. R. Jeppson, Associate in the Experiment Station; and A. D. Borden, Associate Entomologist in the Experiment Station.

TABLE 3

Comparative Tests of Several Insecticides against the Onion Thrips

Composition of insecticides	Per cent reduction 2 days after treatment		Per cent reduction 8 days after treatment	
	Adults	Nymphs	Adults	Nymphs
2.5 quarts of 20 per cent DDT in oil (SH20), 4 ounces sodium oleyl sulfate spreader per 100 gallons water. . .	99	91	96	98
5 pounds 20 per cent DDT wettable powder (A20) per 100 gallons water.	86	93	85	99
3 per cent DDT dust (A3)	98	87	96	99
2 pounds rotenone spray,* 4 ounces sodium oleyl sulfate spreader per 100 gallons water	87	89	65	76
1 pound dinitro powder,† 4 ounces blood albumin per 100 gallons water.	38	61	22 increase	88

*A proprietary product containing 4 per cent rotenone, 8 per cent other cube resins, 17 per cent petroleum oils.

†A proprietary product containing 20 per cent amine salt of dinitro-o-cyclohexylphenol.

TABLE 4

Thrips Populations on Onions after the Application of Dusts Containing DDT

Dust used	Average number adults per plant		Average number nymphs per plant		
	1 day after treatment	14 days after treatment	1 day after treatment	14 days after treatment	21 days after treatment
3 per cent DDT (A3). . .	0.25	4.0	3.3	4.0	6.6
1 per cent DDT*.	0.6	7.7	3.0	15.0	16.0
1 per cent DDT†.	....	4.4	...	3.1	8.4
Check.	2.2	...	6.7	17.3	18.0

*DDT (GNB-A) dissolved in acetone and atomized on pyrophyllite.

†DDT (GNB-A) dissolved in methyl naphthalenes and atomized on pyrophyllite.

population than the 1 per cent dust prepared with acetone.

Six spray combinations were tested on a section of a large block of heavily infested late onions. The materials were applied at the rate of 200 gallons per acre, by means of a power sprayer at 350 pounds' pressure, 3 nozzles being used for each double row. Two replicates were made of each treatment, and two samples were taken from each replicate. Table 5 shows the mean number of nymphs found on 20 onion plants taken at random from the north and south half of the test plots. Two applications were made; and the nymph population was determined 3 and 12 days after the first treatment and 18 days after the second. In one case, a count was also made after 28 days.

The DDT powder (AK20) at a concentration of 1 pound of actual DDT in 100 gallons of water gave the most promising results. When the period between applications was as long as 28 days, however, the thrips population built up.

There were no significant differences in the thrips population of plots sprayed with nicotine sulfate, dinitro with nicotine, or tartar emetic and sugar after the June 23 application. After the treatment on July 5, however, samples indicate better results from nicotine sulfate than from any of the three above combinations. The cool temperature on June 23 was unfavorable for nicotine sulfate treatment, whereas the high temperature prevailing on July 5 undoubtedly influenced the effectiveness of control.

By July, sufficient DDT was secured to treat 15 acres of onions. As the season was well advanced, the only field of young onions available had a relatively poor stand. Of this, a section consisting of 15 acres was selected for the DDT treatment, and the remainder was sprayed with nicotine sulfate. The application was made with a power sprayer at 250 pounds' pressure, 3 nozzles being used to each double row. The rate of application was 220 gallons of diluted spray per acre.

Thrips counts were made from 10 onion plants in each treatment. Table 6 records the treatments used, the dates of application and sampling, the average number of thrips per onion plant, and the yield per acre in each plot.

In this test better control of thrips was obtained with the DDT treatments than with nicotine sulfate. A DDT dosage of 2 pounds of 20 per cent material with soap gave almost as good results as the 5-pound treatments. The omission of soap

TABLE 5

Field Tests with Several Insecticides for Controlling Onion Thrips

Materials used in 100 gallons of spray	Date sprayed	Days after treatment	Average number nymphs per plant
5 pounds of 20 per cent DDT powder (AK20), 4 ounces sodium oleyl sulfate	June 23	3 12 28	8 59 467
5 pounds of 20 per cent DDT powder (AK20), 4 ounces sodium oleyl sulfate	June 23 July 5	3 12 18	7 75 53
5 pounds of 20 per cent DDT powder (AK20), 4 ounces sodium oleyl sulfate	July 5	18	82
2 pounds tartar emetic, 4 pounds sugar	June 23 July 5	3 12 18	43 192 254
1 pint 40 per cent nicotine sulfate, 1 pound soap .	June 23 July 5	3 12 18	44 212 141
1 pound dinitro powder,* 3 pounds nicotine sulfate,† 1 pint kerosene, 8 ounces blood albumin	June 23 July 5	3 12 18	30 221 273
Check			
Sampled June 26			73
Sampled July 5			364

*A proprietary product containing 20 per cent dicyclohexylamine salt of dinitro-o-cyclohexylphenol.
†A proprietary product containing 2.8 per cent nicotine alkaloid and 13.5 per cent petroleum oil.

TABLE 6

Comparison on Thrips Control and Onion Yields after Applications of DDT and Nicotine Sprays

Materials used in 100 gallons of spray	Spray dates	Days after treatment	Average number nymphs per plant	Yield in 100-pound sacks per acre
5 pounds of 20 per cent DDT powder (AK20), 1 pound soap	June 26 July 12	4 16 19 28	41 45 116 488	260
2 pounds of 20 per cent DDT powder (AK20), 1 pound soap	June 26 July 12 July 31	4 16 19 9	44 48 186 163	270
5 pounds of 20 per cent DDT powder (AK20), no soap added	June 26 July 12	4 16 19 28	21 86 119 192	253
1 pint nicotine sulfate 40 per cent, 1 pound soap	June 24 July 7 July 12	6 8 19 28	273 285 353 175*	183

*Onion tops were largely dried up, and conditions were unfavorable for thrips' development.

as a spreader to the 5-pound dosage did not reduce the effectiveness of the spray.

By July 31 the onion tops in the blocks sprayed with nicotine sulfate had begun to die due to the heavy thrips infestation. The result was a decline from 353 thrips per plant 19 days after the July 12 application to 175 thrips per plant on August 9. The onion tops on the plots sprayed with DDT remained green until the middle of August. This prolongation of growth in the area sprayed with DDT was undoubtedly the reason for the increased yield over that of the nicotine sulfate plot.

With flying insects such as onion thrips a migration from one plot to another might be expected, especially when one section of a field having a high thrips population becomes dry and unsuitable for thrips. On August 9 (28 days after the July 12 treatment) 488 thrips per plant were found on the block treated with 5 pounds of DDT and soap. As this plot was adjoining the nicotine-sprayed section of the field, the high thrips population no doubt indicated a migration from the drying onions in the area sprayed with nicotine sulfate.

The increase in yield of the DDT plots over the nicotine-sprayed plots was between 70 and 87 (100-pound) sacks of onions per acre. These figures adequately illustrate the value of keeping the thrips population under control.

TESTS WITH DDT AND OTHER INSECTICIDES FOR CONTROLLING ONION THRIPS IN THE SALINAS VALLEY[15] [16]

Experiments testing DDT as a spray and as a 3 per cent dust (A3) were conducted at Salinas during 1944 on Ebenezer and on White Sweet Spanish onions planted for dehydration.

In the coastal areas of California, damage to onions by the onion thrips, Thrips tabaci Lind., is not often serious enough to prevent harvesting a crop. Evidently, however, the yields are reduced by thrips feeding. According to previous tests conducted during 1942 and also reported here, several nicotine preparations (including nicotine sulfate, nicotine alkaloid, and nicotine bentonite) give unsatisfactory kills of thrips. The use of tartar emetic and sugar on onions also proved unsatisfactory.

In a series of sprays applied July 20, 1942, on Australian brown onions at Salinas, only poor control was obtained by using single applications of several different spray combinations. Table 7 presents these data. The materials were used on approximately 1/3-acre plots with check plots left on each side so that a treated plot could be compared with two adjacent checks. The materials were applied with a Bean sprayer at 400 pounds' pressure. The best control was obtained with a combination spray consisting of cryolite-derris (rotenone extracted in pine oil) and pyrethrum, and with a nicotine sulfate oil spray.

On July 21 and August 23, 1944, spray materials were applied at Salinas to test the efficiency of DDT against onion thrips on onions in comparison with several other recommended treatments. The onions were approximately 60 per cent mature on the date of the first application. The materials used were nicotine sulfate-Vatsol-sugar as recommended by Campbell and Persing,[17] nicotine alkaloid (80 per cent alkaloid), tartar emetic and sugar, a dinitro-nicotine-kerosene mixture, DDT as a spray (GNB-A), and DDT as a 3 per cent dust (A3). The sprays were applied with a Bean sprayer at 400 pounds' pressure, using two 0.035-inch opening fan-type nozzles to a row (four to a bed of two rows), at the rate of 190 gallons to the acre. Only a single application of dust was made by means of a Root rotary hand-duster at the rate of 35 pounds to the acre.

The DDT stock emulsion was prepared as follows:[18]

Material	Parts by weight
DDT	15
Acetone	30
Methyl cyclo-hexanol	15
Sulfonated vegetable oil	36
Ammonium hydroxide	4

In making the emulsion, the DDT is dissolved in acetone over a water bath. The hexanol is added, and then the vegetable oil is poured in very slowly while the temperature is maintained. Finally the ammonium hydroxide is added. The resultant mixture should be thoroughly shaken several times at intervals. Ordinarily it should be used within 10 days. This stock emulsion was used at the rate of one gallon per 100 gallons of water.

The spray plots were of a modified randomized block type, 3 replications of each material being made on 1/3-acre plots. Dust was applied to a single 1/3-acre plot. A total of 32 plots, including checks, were considered in these experiments.

Population counts were made on July 27 and 28, counting adults and nymphs on 25 onion plants from each plot (5 stations of 5 plants each), taken from the center two rows of each plot and in the same relative position in each plot. Table 8 shows the results of this first series of counts.

Judging from these figures, DDT emulsion surpassed any other spray treatment and also the 3 per cent DDT dust. The dinitro spray mixture

[15] Prepared by W. H. Lange, Jr., Junior Entomologist in the Experiment Station; and T. W. Thwaits, Specialist in Agricultural Extension.

[16] For help with the 1944 experiments the authors are indebted to C. Autsen, A. J. Cox, G. Fiscalini, P. A. Kantor, W. Lewis, V. E. Romney, A. Skow, A. A. Tavernetti, and others.

[17] University of California Citrus Experiment Station experiments in 1943 for control of onion thrips in southern California. 1 page. (Mimeo.)

[18] A modification (developed by V. E. Romney) of example no. 1, Soap and Sanitary Chemicals 19(7): 103. July, 1943.

TABLE 7

Results of Spray Treatments for Controlling Onion Thrips at Salinas, Sprayed July 20, 1942

Material (per 100 gallons of spray)	Number of thrips per plant on July 28		Per cent reduction in population	
	Adults	Nymphs	Adults	Nymphs
Tartar emetic, 5 pounds; Karo sirup, 15 pounds.	5.3	44.7	65.1	44.7
Check	13.7	72.3	....	....
Cryolite (98 per cent sodium fluoaluminate), 3 pounds; rotenone extract (5 per cent rotenone), 2 pints; pyrethrum extract (2 per cent pyrethrins), 2 pints	5.0	42.8	66.9	47.0
Check	16.6	89.2	....	....
Nicotine sulfate, 1 pint; light medium oil emulsion, 1 gallon	9.4	45.2	39.4	47.3
Check	14.4	82.4	....	....
Nicotine bentonite, 3 pounds; resin spreader, 2 pints . . .	5.8	86.8	48.7	0.0
Check	8.2	56.2	....	....
Nicotine bentonite, 8 pounds; nicotine sulfate, 1 pint; oil spreader and sticker, 8 ounces	3.8	78.8	59.1	0.0
Check	10.4	91.0	....	....
Pyrethrum,* 1.5 pounds; liquid spreader, 1 pint	1.8	64.6	78.6	34.3
Check	614.0	105.6	....	....

*A proprietary mixture with declared active ingredients: pyrethrins, 1.2 per cent; petroleum oils, 10.0 per cent (minimum sulfonated residue, 90 per cent).

TABLE 8

Results of Onion Thrips Counts Made July 27 and 28, of Twenty-five Onion Plants in Each Plot at Salinas

Material (per 100 gallons of spray except as noted)	Thrips per treated plant		Thrips per untreated plant		Per cent reduction in population*	
	Adults	Nymphs	Adults	Nymphs	Adults	Nymphs
Nicotine sulfate, 1 quart; sugar, 4 pounds; wetting agent,† 450 cc	2.9	8.4	3.1	6.9	6.4	0.0
Emulsion containing 15 per cent DDT (GNB-A), 1 gallon	0.6	0.1	3.5	7.7	82.8	98.7
Tartar emetic, 2 pounds; sugar, 4 pounds	2.3	12.1	3.4	8.3	32.3	0.0
Nicotine alkaloid (80 per cent), 1 pint; wetting agent,† 450 cc	1.9	12.9	3.3	9.7	42.4	0.0
DDT 3 per cent dust (A3), 35 pounds per acre	0.9	1.7	3.1	10.2	71.0	83.3
Dinitro,‡ 1 pound; nicotine powder (2.8 per cent nicotine alkaloid and 13.5 per cent petroleum oil), 3 pounds; kerosene, 1/2 pint; casein spreader, 1/3 pound	1.6	3.0	2.5	7.5	36.0	60.0
Dinitro,‡ 1 pound; kerosene, 1/2 pint; casein spreader, 1/3 pound	2.4	2.7	2.9	7.9	17.2	65.8

*Formula used in computing efficiency of materials is as follows: $\frac{x-y}{x} \times 100$, where x = number of live thrips per onion on untreated check plots, and y = number of live thrips per onion on treated plots.

†Composition: 1.5 pounds of a dioctyl ester of sodium sulfo succinate in 1 gallon of distilled water.

‡Twenty per cent of dicyclohexylamine salt of dinitro-o-cyclohexylphenol.

also gave good reductions in thrips populations, with no perceptible injury to the onions. A dioctyl ester of sodium sulfo succinate was added to this mixture because with casein or blood-albumin spreaders it did not adequately wet the plants. The maximum temperature on July 21 was 58° F, a fact which may partly explain the poor results secured with the nicotine materials.

On August 14 another series of population counts of 25 onion plants from each plot showed no difference between the treated and untreated blocks, except that the DDT spray plots gave a 68.6 per cent reduction in adults and a 61.8 per cent reduction in nymphs.

After the second application of spray materials, August 23, counts on 15 onion plants from certain plots were made from September 12 to 14. The results appear in table 9. As in the previous counts, the DDT emulsion was superior to any of the other treatments. The nicotine materials gave better reductions in numbers of thrips, though the maximum temperature for August 23 was, again, only 58° F. The higher temperatures after the second application may, however, have been a factor in determining the higher kills of thrips.

Discussion of Results

In the 1944 Salinas experiment, DDT as a spray in emulsion form apparently gave the greatest kill of onion thrips on Ebenezer and White Sweet Spanish onions, in comparison with several other recommended treatments. The onions in the DDT spray plots not only showed a reduction in thrips populations, but also exhibited much less silvering of the tops and remained greener several weeks longer than those in the other plots. The control of thrips was also shown by increased yields of onions on two of the DDT spray plots in comparison with adjacent untreated control plots. The yield increases are shown in table 10. These yield figures are not conclusive, but only indicate what might be expected if adequate replications and checks were possible. It would have to be assumed, however, that adjacent plots of this nature would have soils of comparable fertility.

On October 5 a random sample of onion plants was collected from the DDT plots sprayed on July 21 and August 23 and sent to A. J. Cox of the State Department of Agriculture for DDT residue

TABLE 9

Results of Onion Thrips Counts Made from September 12 to 14, of Fifteen Onions in Each Plot at Salinas

Material (per 100 gallons of spray)	Thrips per treated plant		Thrips per untreated plant		Per cent reduction in population*	
	Adults	Nymphs	Adults	Nymphs	Adults	Nymphs
Nicotine sulfate, 1 quart; sugar, 4 pounds; wetting agent,† 150 cc	2.4	26.8	3.1	88.8	22.6	69.8
Emulsion containing 15 per cent DDT (GNB-A), 1 gallon	1.3	13.2	3.1	88.8	58.1	85.1
Tartar emetic, 2 pounds; sugar, 4 pounds	2.4	39.2	1.4	63.6	0.0	38.4
Nicotine alkaloid (80 per cent), 1 pint; wetting agent,† 450 cc	0.9	31.1	1.6	84.4	43.7	63.1
Dinitro,‡ 1 pound; nicotine powder (2.8 per cent nicotine alkaloid and 13.5 per cent petroleum oil), 3 pounds; kerosene, 1/2 pint; casein spreader, 1/3 pound	1.5	28.3	1.7	75.4	11.8	63.8

*Formula used in computing efficiency of materials is as follows: $\frac{x-y}{x} \times 100$, where x = number of live thrips per onion on check plots, and y = number of live thrips per onion on treated plots.

†Composition: 1.5 pounds of a dioctyl ester of sodium sulfo succinate in 1 gallon of distilled water.

‡Twenty per cent dicyclohexylamine salt of dinitro-o-cyclohexylphenol.

TABLE 10

Yield of Ebenezer Onions on Certain Plots at Salinas, Harvested on October 23, 1944

Treatment (DDT in 100 gallons of water)	Pounds of topped onions from 666 square feet (1/65 acre)	Increase in pounds of onions per acre	Total yield of onions in pounds per acre
Emulsion containing 15 per cent DDT (GNB-A), 1 gallon	271.25	1,072.5	17,631
Check	254.75	....	16,559
Emulsion containing 15 per cent DDT (GNB-A), 1 gallon	325.75	4,875.0	21,174
Check	250.75	....	16,299

analysis. The result of this examination is shown in the tabulation below:

	Weight in pounds	DDT, grains per pound	DDT, parts per million
Onion tops	1.05	. . 0.081 . .	11.58
Topped onions. . .	2.90	. . 0.026 . .	3.72
Outer layer of topped onions. .	0.23	. . 0.328 . .	46.90
Peeled onions. . .	2.67	. . Test negative	
Tops and bulb. . .	3.95	. . 0.041 . .	5.86

Judging from this series of analyses, no residue problem is involved, provided the onions are peeled before use.

To control thrips adequately throughout a growing season, spraying operations might well be started during the earlier stages of growth. This schedule might necessitate at least three applications. The fact that spraying onions with DDT would prolong their growth in the fall and retard their drying must be considered in spray operations involving this material.

The use of dinitro may prove a practical control under coastal conditions where burn does not occur. Since, however, no applications were made to small onions, this material must be tried under different circumstances and at various stages of growth before any recommendations can be made.

Summary

The use of single applications of sprays containing tartar emetic, pyrethrum and rotenone extracts, nicotine sulfate, and nicotine bentonite in preliminary experiments conducted in the Salinas Valley during 1942 did not give adequate control of onion thrips on onions.

During 1944 at Salinas, in a comparison of spray treatments, a DDT emulsion was apparently superior to tartar emetic and sugar, nicotine sulfate and sugar, nicotine alkaloid, a dinitro-nicotine-kerosene mixture, and 3 per cent DDT dust.

Two applications of a DDT emulsion (1 pound of DDT to 100 gallons of water), at the rate of 190 gallons to the acre, gave a 98.7 per cent reduction in nymphs on July 27, one week after the first application; a 61.8 per cent reduction 24 days after this spray treatment; and an 85.1 per cent reduction of nymphs 22 days after the second application (made on August 23).

An analysis of onions from plots sprayed twice with the DDT spray mixture indicated that DDT was present on the tops and bulbs. When the onions (bulbs) were peeled, no DDT was found.

Yield records obtained on October 23 from two plots sprayed twice with DDT emulsion gave increased yields of onions when compared with untreated check plots.

Although DDT shows much promise for the control of the onion thrips, further investigations are necessary before this material can be safely recommended for commercial use.

FIELD TESTS WITH DDT TO CONTROL CODLING MOTH ON BARTLETT PEARS[19]

The experimental plot was located in a large commercial Bartlett pear orchard in the Sacramento River area. In 1943 the orchard received 6 lead arsenate sprays; in 1944 it received 7. For the DDT experiment, 8 large trees were selected. When the investigation was started, 2 lead arsenate sprays had already been applied. Single-tree plots were used, and the experimental area was divided into two series. The composition of the spray for one series was 2-1/2 quarts of a 20 per cent DDT in oil with emulsifier (SH20) per 100 gallons of water; for a second series, 5 pounds of 20 per cent DDT wettable powder (A20) per 100 gallons of water. The trees in each series received 2 to 4 applications. Single trees in each of the two series were sprayed on the following dates: May 5 and 22; May 5 and June 14; May 5 and July 6; May 5 and 22, June 14, and July 6.

Close examination of 100 fruits per tree was made just before each application up to harvest time, as well as at harvest. No codling-moth injury was noted at any time. All dropped fruit was carefully inspected for worms, but no entries were found. In an adjoining area that received 7 applications of lead arsenate, applied by the grower, counts of picked and dropped fruit showed not over 2 per cent worms.

The DDT suspension spray caused no discernible injury and gave excellent coverage. The 20 per cent DDT in oil showed poor wetting, and spotted-leaf injury occurred. The fruit drop on the oil-DDT plot at harvest time was nearly 500 fruits per tree, whereas the dry-wettable-sprayed trees showed a drop of 60 fruits apiece, a figure considered normal where no hormone is applied.

Red-spider injury appeared earlier and was more severe in the DDT plots than it was in the remainder of the orchard receiving the regular program of lead arsenate and dinitro. No coccinelid or chrysopid eggs were observed on the fruit or foliage until a few weeks before harvest.

Analysis (see table in the section on spray residues) of the spray residue was obtained from samples of each treatment, taken at harvest. These analyses show a higher deposit of DDT remaining on the fruit when the DDT was combined with oil than the deposit obtained by applying DDT in water-suspension form. Using the present tolerances for arsenic as a standard for comparison, two applications of both materials weathering for 1.5 to 2 months were below the permissible amount. Applications made 30 days before analysis came within the tolerance for the wettable material and near the tolerance for the oil-DDT combination. Four applications, the last of which was made 30 days before analysis, gave

[19] Prepared by A. D. Borden, Associate Entomologist in the Experiment Station; and L. R. Jeppson, Associate in the Experiment Station.

amounts higher than the tolerance with both types of materials. If compared with the tolerance for lead, all DDT deposits were below the permissible amounts. Though no definite tolerance has been prescribed for DDT, the data given above may be of interest in determining such an amount.

DDT TEST IN THE CONTROL OF PEAR BUD MITE[20]

This test was conducted in a Comice pear orchard heavily infested with pear bud mites. A spray consisting of 5 pounds of 20 per cent DDT powder (AK20), 4 ounces of sodium oleyl sulfate, and 100 gallons of water was applied to 6 large trees. On October 2, the date of application, there was a heavy infestation of bud mites under the first bud scales. A population count made a week later showed no apparent kill of the mites.

TEST COMPARING THE EFFECTIVENESS OF DDT AND ROTENONE AGAINST PEAR THRIPS LARVAE[21]

A Bartlett pear orchard at Sunnyvale, heavily infested with thrips larvae, was chosen for the test. A block of 12 trees was randomized to permit 4 treatments with 3 replicates. The plot was treated May 2 with a power sprayer. The insecticides used were an oil solution of DDT, a rotenone spray, and a rotenone spray plus oil. The check plots were sprayed with water. Thrips larvae were counted on 25 fruit clusters from each of the trees before spraying and also 2 and 6 days after application. Table 11 summarizes the results of this test.

TABLE 11

Comparison of DDT and Rotenone Spray Treatments for Controlling the Nymphs of Pear Thrips

Spray materials per 100 gallons spray	Average number nymphs per cluster		
	Before spraying	2 days after spraying	6 days after spraying
20 per cent DDT in oil with emulsifier (SH20), 2.5 quarts	42	3	3
Rotenone spray,* 1.1 pounds, plus 4 ounces sodium oleyl sulfate .	42	4	2
Rotenone spray with spreader, 8 ounces; and tank mix oil, 2 quarts †	33	8	5
Check, sprayed with water	54	24	19

*A proprietary spray containing rotenone 4 per cent, other cubé resins 8 per cent, petroleum oils 17 per cent.

†Unsulfonated residue 90 per cent, viscosity 60.

In this test DDT in oil was as effective as rotenone or rotenone and oil in reducing the population of pear thrips larvae; a spotted injury appeared, however, on the leaves of the trees sprayed with DDT in oil.

TESTS WITH DDT ON TUSSOCK MOTH ATTACKING PEAR[22]

Bartlett pear trees in Santa Cruz County that were infested with tussock moth, Hemerocampa vetusta (Bdv.), were treated May 1, 1944, with a spray containing 2.5 quarts of 20 per cent DDT in oil with emulsifier (SH20) per 100 gallons of water. The control obtained was good, the same as noted on apple in another section. As on apple, the spray caused a spotted leaf injury.

EXPERIMENTS WITH DDT IN OILS APPLIED AS VAPO-SPRAYS FOR CONTROLLING PEA INSECTS[23] [24]

During August and September several mixtures containing oil and DDT were applied to peas as vapo-sprays. The work was done at Gilroy, and observations were made on the population trends of the common pests and parasites present.

The tests were conducted on single, unreplicated plots 18 rows wide (approximately 1 acre) extending through a 10-acre field. Including the check, a total of 9 treatments were compared.

Two applications were made, the first on August 29, and the second on September 20 and 21. About 5 gallons of material was used per acre for each application. The equipment used was a vapo-spray machine. Drop curtains were used for the first application, but not for the second. The peas were planted about July 20 and received the usual dusting with lead arsenate and nicotine when about 3 to 4 inches high. They were 10 to 12 inches tall at the time of the first application, and pods were well formed at the time of the second.

Population Counts

Two methods of obtaining population counts were used in order to evaluate the relative efficiency of the treatments. The first or "knockdown" method consisted of selecting plants at random, preferably in groups of 5, and shaking them vigorously over a large piece of black card-

[20]Prepared by A. D. Borden, Associate Entomologist in the Experiment Station; and L. R. Jeppson, Associate in the Experiment Station.

[21]Same authorship as in footnote 20.

[22]Same authorship as in footnote 20.

[23]Prepared by W. H. Lange, Jr., Junior Entomologist in the Experiment Station.

[24]A coöperative project with the Shell Oil Company. The writer acknowledges the help of Paul R. Jones, C. J. Boissonou, and W. Buchser of that company for assistance in securing field data.

board. The second method was to make 100 sweeps in each plot with an insect net[25] at 3- to 6-day intervals.

According to knockdown counts made on August 30 and September 6 on populations of thrips (chiefly Frankliniella helianthi), a significant decrease in numbers occurred in the plots treated with a spray having 1.2 per cent or higher DDT content (table 12).

TABLE 12

Number of Thrips Present on Five Plants in Each Plot, as Determined by the Knockdown Method

Treatment (per cent by weight of material in a vapo-spray oil)*	Thrips on August 30	Thrips on September 6
DDT, 0.3	152	83
DDT, 0.6	51	54
DDT, 1.2	29	28
DDT, 2.4	22	29
DDT, 1.2; cardolite, 7.5; derris resins, 0.65; rotenone, 0.25	31	43
DDT, 1.2; rotenone, 0.05; cresylic acid, 0.11 . . .	25	40
DDT, 1.2 (lighter oil) . .	22	50
Rotenone, 0.25; derris resins, 0.65; cardolite, 7.5	44	82
Check	90	99

*Composition: 70 per cent mineral seal oil of 45 to 50 viscosity (90 U.R.); and 30 per cent kerosene.

On September 30 the knockdown method was used to determine the populations of pea aphids in the different plots. Judging from preliminary counts, the examination of a few single plants did not adequately allow for the spotted nature of pea aphid populations in the field. For this reason, in each plot 5 plants were examined from 10 stations, for a total of 50 plants. According to these counts, the treatments containing 2.4 per cent DDT or 1.2 per cent DDT and rotenone in combination gave the greatest reductions in aphid populations. DDT concentrations of less than 1.2 per cent were ineffective. Table 13 gives these results.

In addition to these knockdown counts, 100 sweeps of the insect net were taken in each plot on the following dates: August 30; September 6, 18, 21, 23, 26, and 30. All of the common insects except thrips were counted. Table 14 shows the populations. The sweeps were made during the hours between 10:30 a.m. and 1:30 p.m. To summarize the results of these sweeping samples: it seems that next to thrips, which cannot be adequately counted by this method, the commonest insect was the pea aphid, Macrosiphum onobrachis (B. de Fonsc.). Other insects commonly taken in the sweepings included adults of the pea leaf miner, Liriomyza flaveola (Fallen);

TABLE 13

Number of Aphids on Fifty Plants in Each Plot on September 30, as Determined by the Knockdown Method

Treatment* (per cent by weight of material in a vapo-spray oil)	Number of aphids
DDT, 0.3	1,460
DDT, 0.6	1,044
DDT, 1.2	568
DDT, 2.4	511
DDT, 1.2; cardolite, 7.5; derris resins, 0.65; rotenone, 0.25 . . .	376
DDT, 1.2; rotenone, 0.05; cresylic acid, 0.11	250
DDT, 1.2 (lighter oil)	347
Rotenone, 0.25; derris resins, 0.65; cardolite, 7.5	748
Check	1,638

*Composition: 70 per cent mineral seal oil of 45 to 50 viscosity (90 U.R.); and 30 per cent kerosene.

adults of a predaceous fly, Thaumatomyia (Chloropisca) glabra (Meigen); adults of Diabrotica 11-punctata (Mann.); various parasites of the pea leaf miner (small wasps of the genus Solenotus are the commonest); Lygus bugs; and several lepidopterous larvae.

Besides these insects, a white fly was abundant on peas, although no counts were made. Apparently none of the treatments greatly reduced the numbers of adult flies. Only two specimens of the pea weevil were taken, one on September 18 and another on September 26. The false chinch bug migrated into the plots toward the end of September, apparently irrespective of any treatments. A fulgorid, Cixius cultus Ball, was taken in limited numbers. The lepidopterous larvae present included a small armyworm of unknown species, looper larvae of the genus Autographa, and occasionally a larva of the alfalfa butterfly.

Results

From the standpoint of pea aphid control, DDT appears to be fairly effective in oil when applied by the vapo-spray machine; the kill is in direct proportion to the amount of DDT present. The mixture containing 2.4 per cent DDT was the most effective and, as already noted, was comparable with the 1.2 per cent DDT and rotenone combinations.

In evaluating the degree of aphid control with the different concentrations of DDT, it was found that if curves were made depicting the total number of aphids collected by the sweeping method

[25] The frame of the net is an ellipse, the major axis of which is 15 inches and the minor axis 13 inches.

TABLE 14

Populations of Insects Collected per 100 Sweeps of an Insect Net
(Field was treated August 29 and September 20 and 21, 1944)

Treatment (per cent by weight of materials in a vapo-spray oil)	Counts of insects on the survey dates given							
	Aug. 30	Sept. 6	Sept. 18	Sept. 21	Sept. 23	Sept. 26	Sept. 30	Total counted
Adults of the pea aphid, *Macrosiphum onobrachis*								
DDT, 0.3	30	47	145	200	293	590	106	1,381
DDT, 0.6	8	32	142	152	290	355	138	1,117
DDT, 1.2	1	10	52	53	151	138	102	507
DDT, 2.4	4	4	26	30	51	104	28	257
DDT, 1.2; cardolite, 7.5; derris resins, 0.65; rotenone, 0.25	7	5	34	15	54	73	51	239
DDT, 1.2; rotenone, 0.05; cresylic acid, 0.11	5	6	11	34	76	36	26	194
DDT, 1.2 (lighter oil)	2	3	26	21	57	85	43	237
Rotenone, 0.25; derris resins, 0.65; cardolite, 7.5	7	9	32	46	28	59	27	208
Check	22	41	115	186	461	412	87	1,324
Adults of *Lygus hesperus*								
DDT, 0.3	3	9	1	1	5	9	1	29
DDT, 0.6	0	5	5	2	5	2	0	19
DDT, 1.2	0	2	2	0	2	1	1	8
DDT, 2.4	0	1	0	0	0	1	0	2
DDT, 1.2; cardolite, 7.5; derris resins, 0.65; rotenone, 0.25	0	1	1	0	2	1	0	5
DDT, 1.2; rotenone, 0.05; cresylic acid, 0.11	0	0	2	1	0	3	0	6
DDT, 1.2 (lighter oil)	0	0	1	0	0	2	0	3
Rotenone, 0.25; derris resins, 0.65; cardolite, 7.5	0	0	0	0	0	2	0	2
Check	1	1	1	1	1	2	1	8
Adults of *Diabrotica 11-punctata*								
DDT, 0.3	1	6	7	15	6	14	0	49
DDT, 0.6	0	3	5	9	10	12	1	40
DDT, 1.2	0	1	6	9	5	5	2	28
DDT, 2.4	0	0	5	5	1	1	0	12
DDT, 1.2; cardolite, 7.5; derris resins, 0.65; rotenone, 0.25	0	1	4	0	1	4	1	11
DDT, 1.2; rotenone, 0.05; cresylic acid, 0.11	0	1	4	2	3	3	0	13
DDT, 1.2 (lighter oil)	0	1	2	4	4	3	0	14
Rotenone, 0.25; derris resins, 0.65; cardolite, 7.5	0	1	3	4	1	3	0	12
Check	1	1	4	4	0	0	1	11
Adults of the pea leaf miner, *Liriomyza flaveola*								
DDT, 0.3	25	72	30	47	7	121	57	359
DDT, 0.6	8	67	50	72	41	116	103	457
DDT, 1.2	0	11	183	64	24	47	106	435
DDT, 2.4	6	4	228	61	54	75	72	500
DDT, 1.2; cardolite, 7.5; derris resins, 0.65; rotenone, 0.25	1	67	178	63	16	76	120	460
DDT, 1.2; rotenone, 0.05; cresylic acid, 0.11	9	3	209	110	38	46	44	459
DDT, 1.2 (lighter oil)	1	1	18	126	8	58	24	236
Rotenone, 0.25; derris resins, 0.65; cardolite, 7.5	5	12	66	6	4	12	33	138
Check	259	45	21	128	48	58	214	773
Adults of a dipterous aphid predator, *Thaumatomyia glabra*								
DDT, 0.3	2	20	260	213	87	157	52	791
DDT, 0.6	0	15	58	129	134	120	49	505
DDT, 1.2	1	0	26	19	62	59	63	230
DDT, 2.4	0	1	2	1	12	30	24	70
DDT, 1.2; cardolite, 7.5; derris resins, 0.65; rotenone, 0.25	0	0	5	0	17	29	41	92
DDT, 1.2; rotenone, 0.05; cresylic acid, 0.11	5	0	8	5	17	16	7	58
DDT, 1.2 (lighter oil)	0	0	4	10	13	10	11	48
Rotenone, 0.25; derris resins, 0.65; cardolite, 7.5	4	0	8	4	33	46	54	149
Check	2	0	6	124	156	55	31	374

TABLE 14 (Continued)

Treatment (per cent by weight of materials in a vapo-spray oil)	Counts of insects on the survey dates given							
	Aug. 30	Sept. 6	Sept. 18	Sept. 21	Sept. 23	Sept. 26	Sept. 30	Total counted
Lepidopterous larvae (figures followed by a represent green armyworms; by b, loopers [Autographa sp.])								
DDT, 0.3	0	0	0	0	0	0	0	0
DDT, 0.6	0	0	0	0	0	0	0	0
DDT, 1.2	0	0	0	0	0	0	0	0
DDT, 2.4	0	0	1a	0	0	0	0	1a
DDT, 1.2; cardolite, 7.5; derris resins, 0.65; rotenone, 0.25	0	0	0	0	0	0	0	0
DDT, 1.2; rotenone, 0.05; cresylic acid, 0.11	0	0	0	0	0	0	0	0
DDT, 1.2 (lighter oil)	0	0	0	0	0	0	0	0
Rotenone, 0.25; derris resins, 0.65; cardolite, 7.5	0	0	10a	0	0	0	0	1a
Check	0	0	0	8b	2a	7b	5b	2a 20b
Adults of larval parasites, Solenotus spp., of the pea leaf miner								
DDT, 0.3	0	27	1	8	2	68	216	322
DDT, 0.6	0	45	5	17	5	46	408	526
DDT, 1.2	0	4	17	2	8	49	234	314
DDT, 2.4	1	5	17	1	1	21	113	159
DDT, 1.2; cardolite, 7.5; derris resins, 0.65; rotenone, 0.25	1	5	7	1	2	25	146	187
DDT, 1.2; rotenone, 0.05; cresylic acid, 0.11	0	1	21	1	7	12	88	130
DDT, 1.2 (lighter oil)	0	4	3	7	4	17	78	113
Rotenone, 0.25; derris resins, 0.65; cardolite, 7.5	0	5	11	0	1	6	121	144
Check	5	23	10	52	67	68	261	486
Adults of pea leaf miner parasites of the family Chalcididae								
DDT, 0.3	1	15	2	7	2	11	6	44
DDT, 0.6	1	3	2	5	7	9	22	49
DDT, 1.2	1	2	3	0	3	7	77	90
DDT, 2.4	0	1	4	1	3	11	26	46
DDT, 1.2; cardolite, 7.5; derris resins, 0.65; rotenone, 0.25	0	2	6	0	1	6	38	53
DDT, 1.2; rotenone, 0.05; cresylic acid, 0.11	1	1	5	3	5	6	74	95
DDT, 1.2 (lighter oil)	1	2	0	7	2	6	24	42
Rotenone, 0.25; derris resins, 0.65; cardolite, 7.5	0	2	4	4	1	2	34	47
Check	5	11	2	6	3	1	70	98

(a total of 700 sweeps of the insect net during the period August 30 to September 30), data from table 14 compared favorably with the total number of aphids collected on September 30 by the knockdown method (from 50 pea plants, data from table 13). This marked similarity in the control obtained as determined by the two sampling methods tends to substantiate the results, although the correlation in actual number of aphids is one of chance sampling.

There was no sign of any correlation of DDT treatments with the control of adults of the pea leaf miner. The fact that adults moved into the field from a nearby sugar-beet field might make the data misleading. There was a reduction in the degree of mining on the lower leaves of the plants in plots treated with the higher concentrations of DDT and DDT plus rotenone.

The larvae of Thaumatomyia glabra are common predators on the sugar beet root aphid. After harvest of the beets, adults of this fly moved into the pea fields in large numbers. At times they are more abundant than those of the pea leaf miner. Judging from the population trends of this insect, the higher DDT concentrations and DDT and rotenone mixtures may have affected the adults of this fly. The location of the plots, however, might give a similar population trend regardless of treatment.

Parasites of the genus Solenotus were noticeably reduced in the plots that contained the higher concentrations of DDT and DDT and rotenone. These larval parasites of the pea leaf miner emerged in large numbers toward the end of September. There was, however, apparently no correlation with the treatments in relation to numbers of chalcids, several of which emerged through the pupae of the pea leaf miner.

All the treatments seemed effective on lepidopterous larvae, although the populations were not great enough to justify much emphasis on the results.

The populations of diabrotica beetles and lygus bugs were not considered adequate to show the effect of the treatments on these particular insects.

Analyses for DDT residue on pods and kernels are given in the section on analysis of residues. These show that the residue deposit increased along with the amount of DDT in the oil. No evidence of residue could be detected in the kernels from the treatment that contained 2.4 per cent DDT.

Summary

Application of DDT in an oil as vapo-spray at different concentrations indicated that the kill of pea aphids was directly proportional to the amount of DDT present. The highest concentration used, 2.4 per cent by weight, gave the best reduction in populations of aphids.

Combinations of 1.2 per cent DDT and 0.05 or 0.25 per cent rotenone were superior to 1.2 per cent DDT alone, and about the same as 2.4 per cent DDT.

There was some indication that DDT in oil was effective at higher concentrations on flower thrips, white flies, and lepidopterous larvae.

The higher concentrations of DDT seemed to have an effect in reducing populations of a predaceous fly, Thaumatomyia glabra, and parasites of the genus Solenotus (parasites on larvae of the pea leaf miner). No apparent effect was obtained on chalcid parasites of the pea leaf miner.

No definite information concerning the effect of DDT on adult pea leaf miners was obtained. Apparently, however, the maggots did less damage to the lower leaves of the plants in the treated areas.

The populations of diabrotica beetles and lygus bugs were not sufficient to justify any conclusions regarding the effect of DDT on these insects.

Analyses of pea pods and kernels from plots treated with different percentages of DDT indicated the presence of DDT on pods, but its absence on kernels. The amount of DDT present on the pods was proportional to the percentage of DDT used.

FIELD TEST WITH DDT AND SULFUR AGAINST THE POTATO LEAFHOPPER ON POTATOES GROWN FOR SEED[26]

In the work with the potato leafhopper, Empoasca abrupta DeL., the experiment was conducted with Early Rose seed potatoes growing on peat land. The plots, 25 by 30 feet, were replicated twice. DDT and sulfur dusts were tested alone and in combination with one another. They were applied with a rotary hand-duster on August 21, when the plants were 35 days from planting and about 10 inches high. Nymphs were counted 2, 11, and 19 days after treatment. The counts were made on the third and fourth leaves from the base of the plants because these were found to be the most heavily infested. Table 15 gives the results.

TABLE 15

Results of Tests with DDT and Sulfur Dusts in Controlling Potato Leafhopper on Potatoes

Dust materials	Average number of leafhopper nymphs on 20 leaves		
	2 days after dusting	11 days after dusting	19 days after dusting
3 per cent DDT dust (H3)	12	2	4
Check	157	225	184
20 per cent DDT powder (AK20), 5 pounds; dusting sulfur, 95 pounds	26	14	6
Check	165	150	130
Dusting sulfur 100 per cent	No sample	79	54
Check	No sample	166	104

In this test the 3 per cent DDT dust alone, or the 1 per cent DDT dust with sulfur, reduced the leafhopper-nymph population and held it for at least 19 days. Dusting sulfur reduced the number of nymphs by about 50 per cent.

TESTS WITH DDT FOR THE CONTROL OF CERTAIN SCALE INSECTS[27]

The object of these experiments was to determine the toxicity of DDT residues to the subsequent settling of scale crawlers.

Three types of experiments were conducted, as follows: (1) laboratory tests made; (2) branches of host plants treated in the field with a hand-sprayer; (3) trees or bushes treated with a power-driven sprayer.

Laboratory Tests with Olive Scale, Parlatoria oleae (Colvée)

In the laboratory two experiments were made. In the first test twelve different sprays (not listed here) containing DDT were applied to Japanese privet leaves. After the sprays dried, the leaves were infested with olive scale crawlers through contact with heavily infested unsprayed leaves. Ten days later some live scales were present on all sprayed leaves. The higher the viscosity of the oil used with DDT, the greater the number of dead crawlers.

[26]Prepared by L. R. Jeppson, Associate in the Experiment Station; and A. D. Borden, Associate Entomologist in the Experiment Station.

[27]Prepared by E. M. Stafford, Junior Entomologist in the Experiment Station.

In the second test (of 7 spray treatments used) the highest concentrations were as follows:

1. Five pounds of 20 per cent DDT wettable powder (A20) per 100 gallons of dilute spray.
2. Kerosene with 6 grams of DDT (GNB-A) per 100 milliliters, at the rate of 3 gallons per 100 gallons of dilute spray, plus emulsifier (phthalic glyceryl alkyd resin, 1:3200).
3. Mineral seal oil with 4 grams DDT (GNB-A) per 100 milliliters, at the rate of 3 gallons per 100 gallons of dilute spray, plus emulsifier (phthalic glyceryl alkyd resin, 1:3200).
4. Five per cent DDT in emulsible light oil (SH5) at 2 gallons per 100 gallons of dilute spray.

These spray mixtures were applied to Italian jasmine twigs. After 1 week the twigs were infested as in the first experiment; and 10 days later, the order of increasing effectiveness of these treatments in controlling crawlers was 1, 2, 3, and 4. Some dead first-instar settled stages were found, but there were some live scales on all the sprayed leaves.

Limited Field Experiments with Olive Scale

In the field three experiments were made by using a compressed-air sprayer to treat branches heavily infested with scales. The experiments were as follows:

In the first test several different sprays containing DDT were applied to Japanese privet on April 13, before the scale eggs had started to hatch. None of these proved effective. The one showing the highest percentage (7.3 per cent) of dead second-instar scales 33 days after treatment, however, was a spray containing 5 per cent DDT in emulsible light oil base at 1/2 gallon per 100 gallons of water.

The second test was made May 30 on olives when the peak of hatching had been passed. The following spray mixtures were used:

1. Kerosene with 4 grams of DDT (GNB-A) per 100 milliliters at the rate of 3 gallons per 100 gallons of dilute spray, with emulsifier (phthalic glyceryl alkyd resin, 1:3200).
2. Four pounds 20 per cent DDT wettable powder (A20) per 100 gallons of dilute spray.
3. Mineral seal oil with 4 grams of DDT (GNB-A) per 100 milliliters at the rate of 2 gallons per 100 gallons of dilute spray, with emulsifier (phthalic glyceryl alkyd resin, 1:3200).
4. Five per cent of DDT in emulsible light oil (SH5) at 2 gallons per 100 gallons of dilute spray.

Forty-four days after treatment, live young scales could be found on the sprayed leaves. Many live recent adult females could be found in unprotected places on older leaves that had been sprayed with mixtures 1 and 2. Where mixture 3 had been applied, only a few live recent adult females could be found on the older leaves that were unprotected by the shells of old adult females. Leaves sprayed with mixture 4 showed almost no live recent adult females unprotected by old shells. On untreated leaves most of the live scales were recent adult females, though a few second-instar larvae were present.

The third test was made on Italian jasmine on August 11, when hatching of the second brood of scale eggs was still incomplete. The following spray mixtures were compared:

1. Kerosene with 6 grams of DDT (GNB-A) per 100 milliliters at the rate of 2 gallons per 100 gallons of dilute spray, with emulsifier (phthalic glyceryl alkyd resin, 1:3200).
2. Kerosene with 6 grams of DDT (GNB-A) per 100 milliliters at the rate of 4 gallons per 100 gallons of dilute spray, with emulsifier (phthalic glyceryl alkyd resin, 1:3200).
3. Mineral seal oil with 4 grams of DDT (GNB-B) per 100 milliliters at the rate of 2 gallons per 100 gallons of dilute spray, with emulsifier (phthalic glyceryl alkyd resin, 1:3200).

Forty-six days after the sprays were applied, young leaves that were sprayed showed fewer scales than untreated ones. On older leaves more live scales were found in unprotected places where kerosene-DDT sprays were applied than where mineral seal oil-DDT was used. When the mixture was kerosene-DDT, second-instar and recent adult females were observed among DDT crystals on the leaves. After 84 days, a survey was made to determine what proportion of recent adult female scales on the leaves were unprotected by old overlapping females. When 100 recent adult females were counted from each of the 3 treatments and from unsprayed leaves, the per cent of those unprotected by old overlapping females was as follows: unsprayed leaves, 82; treatment 1, 54; treatment 2, 42; and treatment 3, 20.

Field Experiments with Olive Scale Using a Power-Driven Sprayer

In these tests the following spray mixtures were used:

1. Two pounds of 20 per cent DDT wettable powder (A20) per 100 gallons of water.
2. Five per cent of DDT in emulsible light oil (SH5) at 1/2 gallon per 100 gallons of water.
3. Same as mixture 2 but used at the rate of 1 gallon per 100 gallons of water.
4. Four pounds of a talc powder containing 20 per cent of DDT (GNB-A) and 1 quart of heavy medium soluble oil per 100 gallons of water.

The mixtures were applied with a Friend sprayer at 500 pounds' pressure. Spray mixture 1 applied on April 22 to olive trees failed to prevent scale crawlers from settling in a normal manner. On April 24 one Italian jasmine plant was sprayed with mixture 2, and a second with mixture 3. Thirty-four days later most of the scales present were in the second instar, and very few dead young scales could be found on either of these trees. On July 17, before the hatching of the second brood of scale eggs, an olive tree was sprayed with mixture 4. Two days

later a count of 500 adult female scales showed 79.6 per cent to be dead. In early November, however, many live overwintering scales were found, as well as an abundance of scale-spotted olives.

Information on DDT deposit residue on olive foliage and fruit is given in the section on residues.

Conclusion: In none of the tests conducted with *Parlatoria* scale were the results satisfactory for commercial practice. Control of olive scale always increased with viscosity and concentration of oil regardless of concentration of DDT. Even fresh deposits of DDT did not prevent many crawlers from settling and reaching the second instar. The use of DDT seems, therefore, to offer no solution to the problem of controlling olive scales that settle under their mothers' shells.

Tests on Fig Scale, *Lepidosaphes ficifoliae* (Berlese)

Field tests of DDT residues for controlling fig-scale crawlers were unsuccessful in all but one doubtful case. In this case an Adriatic fig tree was treated with a power-driven tree sprayer, using a talc powder containing 20 per cent DDT (GNB-A) at 4 pounds per gallon plus 1/4 per cent heavy medium soluble oil. The spray was applied July 17, when most of the fig-scale population on the stems and upper surfaces of leaves was in the first instar. The scales on the under surfaces of the leaves were mostly adult females. On November 2, very few adult overwintering females could be found on the 1944 wood. This fact would indicate either a high reduction of the population in July or a residual toxicity of the DDT to crawlers. It is not known what control a 1 per cent heavy medium oil spray would give if applied alone in July.

Tests with Black Scale, *Saissetia oleae* Bern

Two field experiments were conducted to determine the effectiveness of DDT in controlling black scale on olives.

In the first experiment at Madera, California, sprays were applied on May 26 before the hatching of the black-scale eggs. Two spray mixtures were tested:

1. Mineral seal oil containing 6 per cent DDT (GNB-A) at the rate of 1.25 gallons per 100 gallons of water, plus 4 ounces of blood albumin.

2. Two pounds of a talc powder containing 20 per cent DDT (GNB-A), 1/4 per cent heavy summer oil, and 4 ounces of blood albumin, per 100 gallons of water.

On July 31, live and dead young scales were counted. The per cent dead in untreated trees and treated trees was as follows: untreated, 36.8; treatment 1, 53.1; treatment 2, 52.6.

The treatments compared in the second experiment are given in table 16. The sprays were applied at Orland, California, on July 27, several weeks after the scale eggs had begun to hatch. Three weeks later, 100 heavily infested leaves from each treatment were searched for live young scales. Also, for each treatment, 50 adult females from the undersides of leaves were examined for live eggs and crawlers. The table gives the results of these examinations.

Although both treatments gave about equal control of adult females, apparently the crawlers were more efficiently controlled with the oil-DDT than with the oil-derris spray. A possible explanation might be that crawlers from surviving females were unable to settle on leaves sprayed with DDT.

TABLE 16

Comparative Effectiveness of an Oil-DDT and an Oil-Derris Spray in Controlling Black Scale on Olives

Treatment	Per cent of leaves with live scales	Per cent of adult females with live eggs and crawlers
2 gallons of a light medium soluble oil containing 5 per cent DDT (GNB-A) per 100 gallons of water. . .	1.0	26.0
1 gallon heavy medium oil, 1/2 pound of derris root containing 5 per cent rotenone per 100 gallons of water	10.0	28.0

DDT shows promise as a control of black scale on olives. Before recommendations are made, further evidence of control should be obtained, and the presence or absence of harmful residues should be determined.

SPRAYING WITH DDT IN A GREENHOUSE TO CONTROL THRIPS, THE VECTORS OF SPOTTED WILT IN TOMATOES[28] [29]

Spotted wilt, a virus disease transmitted by thrips, is an important problem for many tomato growers in the San Francisco Bay region. It is particularly serious near the town of San Pablo; if the thrips are not controlled, greenhouse tomatoes are not profitable. In this area one grower who has specialized in producing tomatoes under glass obtains a fine quality of off-season

[28]Prepared by M. W. Gardner, Professor of Plant Pathology and Plant Pathologist in the Experiment Station; A. E. Michelbacher, Assistant Entomologist in the Experiment Station; and Ray F. Smith, Senior Laboratory Technician, Division of Entomology and Parasitology.

[29]Acknowledgment is made of the wholehearted coöperation and assistance of Mr. and Mrs. Francis Aebi of the Aebi Nurseries, Richmond, California.

tomato by controlling thrips with frequent fumigations with nicotine. He grows a late fall-winter and a spring crop.

Spotted wilt is most troublesome in the late fall-winter crop. This crop is started in July and is transplanted from flats to the greenhouse beds in August. The thrips problem and therefore the spotted-wilt menace are most troublesome from this time on. The threat ends, however, with the advent of the first heavy fall rains, which greatly reduce the thrips population. In the late summer and fall, satisfactory control of thrips and spotted wilt is obtained only by fumigating with nicotine twice a week. Without this treatment it has proved impossible to grow a satisfactory greenhouse tomato crop. Even with the precautions taken, some spotted wilt develops. About once a week, therefore, the greenhouses are carefully examined, and the infected plants removed. In the early stages of growth, these culls are replaced with new plants or with lateral shoots from adjacent plants. After the first heavy rains, fumigation with nicotine is continued; but treatments are spaced much farther apart and finally stopped altogether.

In the experiment here reported, spraying with DDT was compared with nicotine fumigation for controlling thrips and reducing spotted wilt. On August 3, 34 flats of newly transplanted tomato seedlings were treated with a 3 per cent DDT dust to determine whether damage would result. The dust was applied rather heavily but uniformly. Although some injury occurred to the margins and tips of the leaves, the plants outgrew this by the time they were ready to be transplanted into the greenhouse beds.

The experiment was conducted with a battery of three similar adjacent greenhouses. According to the grower's previous experience, the houses did not differ markedly as to infection by spotted wilt. In one of these, DDT was used; in the others, nicotine fumigation. The DDT was applied as a spray, and in all there were 4 treatments. The composition of the spray for the first 3 applications was as follows:

20 per cent DDT powder (AK20) . . .	5 pounds
Blood albumin	6 ounces
Water	100 gallons

The DDT and blood albumin were mixed dry, then slurried, and added to the spray tank when it was half full. For the fourth application 1 pound of pure commercial DDT (GNB-A) was used per 100 gallons of water. The DDT was mixed dry with 6 ounces of blood albumin. Then a little water was added, and the whole slurried. There was difficulty in getting the DDT into suspension. That which went into suspension, however, was decanted off into a half-full spray tank. The residue was again slurried by means of the spray nozzle, and the suspension poured into the tank. This procedure was repeated many times, until only an ounce or so of the residue remained. The deposit of DDT on the tomato foliage, as determined by analysis, was less with this mixture than with the spray mixture used for the first three applications.

Sprays were applied on August 21, September 5, 16, and 30. By September 30 the vines had set fruit the size of marbles, and further treatments would probably have created a residue problem. The first spray was applied at a pressure of 325 to 400 pounds. The plants and all inner surfaces of the greenhouse were sprayed. The coverage on the foliage, though somewhat spotty, was good. To avoid breaking off the plants by the force of the spray, the pressure for the second application was reduced to 125 to 150 pounds. This time only the plants and the supporting poles were treated. Good coverage was obtained. The third spray was applied at 250 to 270 pounds' pressure. The coverage, though fair, was somewhat spotty. An even coverage was obtained with the fourth spray, applied at 300 pounds.

About September 16 some slight injury to the lower leaves of the DDT-treated plants was noted. This became apparent between the second and third spray applications. The injury became progressively worse; on September 26 it appeared as shown in figure 2, B and C. It first showed up as a yellowing between the main lateral veins and around the margin of the leaflet, followed promptly by a tan-colored papery necrosis of the tissue, first around the margin, then all over the leaflet. The plants in the DDT-sprayed

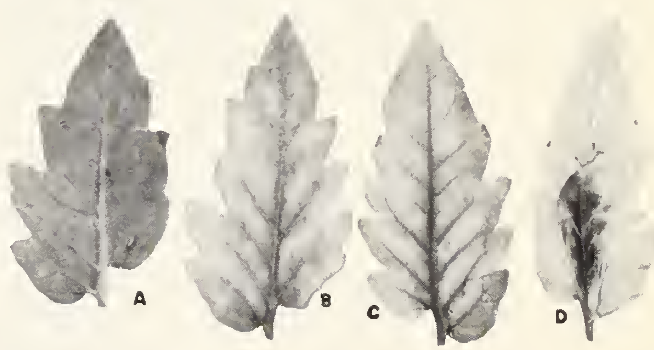

Fig. 2.--Injury to tomato leaflets caused by spraying with DDT. A, Normal leaflet. B and C, Sprayed leaflets showing interveinal and marginal yellowing. D, Sprayed leaflet in final stages of injury, showing tan-colored, papery drying out of the marginal tissues.

house appeared to be lighter green and less stocky than those in the fumigated houses. The dwarfing effect as of September 26 was reflected in leaf length. For the sprayed plants the basal leaves averaged 9.3 inches, and those from the center, 10.5 inches, as compared with 11.6 and 15.2 inches, respectively, the average leaf lengths for the unsprayed plants. The sprayed plants were slightly taller: their average height was 38.7 inches, whereas the plants from the unsprayed houses measured 37.6 inches. This slight difference in height was offset by the more stocky and vigorous growth of the unsprayed plants.

The injured basal leaves showed no signs of recovery; by October 25 many of them had completely dried up. By November 6, foliage injury had sometimes extended 2-1/2 feet up the plants. A leaflet near the final stage of injury is shown in figure 2, D. In the unsprayed houses the lower leaves remained a normal green. The sprayed plants set considerable fruit, but the first clusters did not size so well as on the unsprayed plants.

Table 17 summarizes the information comparing the DDT-sprayed house with the nicotine-treated houses. The greenhouse sprayed with DDT showed less spotted wilt than either of the houses that were fumigated with nicotine. Apparently, then, this material controlled the thrips more efficiently than did the nicotine. Since 2 to 3 weeks is required for the symptoms of spotted wilt to appear, the DDT sprays were presumably responsible for the control up to and including the October 25 rogueing. Thereafter any control was probably the result of the nicotine fumigations which, starting October 9, were substituted for the DDT treatment. Towards the last of October, heavy rains ended any serious threat of spotted wilt. The DDT therefore proved very effective in controlling thrips and spotted wilt during the most critical period.

The foregoing results were substantiated in a greenhouse of 418 plants that was located near by. Because of leaky conditions, this house could not be satisfactorily fumigated with nicotine. It was therefore sprayed 3 times with DDT (September 5, 16, and 30). Only a very few plants became infested with spotted wilt. The spray caused some injury, although less severe than in the house where the principal experiment was conducted.

The DDT residue on various portions of the tomato plants was analyzed. The results appear in the section on residues. There was a relatively high deposit of DDT on the basal leaves, the leaves which finally died.

Conclusions

Under greenhouse conditions, a DDT spray (1 pound of DDT per 100 gallons), applied approximately every 2 weeks, controlled thrips and reduced spotted wilt of tomatoes more effectively than did frequent fumigation with nicotine. Since, however, the treatment seriously damaged the plants, it cannot be recommended unless further experiments show that such injury can be avoided.

Summary

In a region where spotted-wilt virus transmitted by thrips limits the production of a late-fall greenhouse crop of tomatoes, four applications of a DDT spray were made, at fortnightly intervals (August 21, September 5, 16, and 30) during the critical infection period in 1 of 3 similar adjacent greenhouses. In the other 2 houses the standard fumigation with nicotine 2 times per week was applied. The infected plants were removed every week. By October 25 only 137 cases had occurred among the 1,421 plants in the sprayed house, as compared with 161 cases in one fumigated house containing at first 1,427 plants. There were 318 cases in the other fumigated house containing at first 1,456 plants.

The DDT sprays injured the plants rather se-

TABLE 17

Summary of Information on a Comparison of DDT with Nicotine Fumigation for Controlling Thrips and Spotted Wilt on Tomatoes Grown in Greenhouses

Greenhouse no.	Treatment of greenhouse	Number of plants in greenhouse at start	Number of spotted-wilt plants removed on the dates given*							Total infested plants removed by October 25
			Sept. 7	Sept. 11	Sept. 18	Sept. 25	Oct. 5	Oct. 12	Oct. 25	
1	Sprayed with DDT August 21, September 5, 16, and 30;† fumigated with nicotine on October 9, 11, and then twice a week until November 7, and once a week thereafter until November 30.	1,421	22	25	22	14	23	20	9	135
2	Fumigated with nicotine twice a week up to November 7, then once a week until November 30.	1,427	12	37	32	19	14	24	22	160
3	Fumigated with nicotine twice a week up to November 7, then once a week until November 30.	1,456	11	25	76	32	73	27	71	315

*Later inspections resulted in the removal of additional spotted-wilt plants as follows: November 3, 11 from greenhouse 1, 25 from greenhouse 2, and 11 from greenhouse 3; December 4, 18 from no. 1, 28 from no. 2, and 26 from no. 3.

†Amount of spray used August 21, 200 gallons; September 5, 185 gallons; September 16, 230 gallons; and September 30, 170 gallons.

verely, however, causing yellowing between the main veins and around the margins of the leaflets, followed by marginal drying of the leaflets and eventual death of the lower leaves up to a height of about 2-1/2 feet. There was also evidence of retarded growth and a markedly reduced yield.

LABORATORY TESTS WITH DDT ON TRUCK-CROP INSECTS[30 31]

In the spring of 1944 a series of laboratory experiments were conducted with different concentrations of DDT on several common insects affecting truck crops in the Salinas Valley.

The mixtures used were as follows: vapo-sprays containing 0.3, 0.6, 1.2, 2.4, and 3.6 per cent by weight of DDT in 30 per cent kerosene and 70 per cent mineral seal oil; and dusts containing 1 and 3 per cent DDT (both in pyrophyllite). The usual procedure was to run three series: first, an application of the material to potted broccoli plants on which insects were placed within 1 hour; second, direct application to the insects, and their transfer to unsprayed or undusted plants; third, application to broccoli or alfalfa plants, on which insects were placed at later intervals. The plants or insects were treated in the lathhouse and moved inside a greenhouse for observation. Circular cages of cloth were placed over the plants, and a strip of cotton sealed the space between the flower pots and the cage.

The insects tested included adults of *Diabrotica 11-punctata* (Mann.); adults of *Lygus hesperus* Knight; larvae of the vegetable weevil, *Listroderes obliquus* Gyllen.; and adults and larvae of the potato tuber moth, *Gnorimoschema operculella* (Zeller). Insects to be treated were placed in small, fine-wire gauze cages. The vapor sprays were applied as three puffs from a Brown hand gun held 15 inches away. This would correspond to a treatment of about 5 gallons per acre. The plants sprayed were given two puffs from each of two sides at a distance of 16 inches, equal to about 6 gallons per acre. Dusts were applied in the same manner with a small hand-duster. The amount was estimated at 35 to 40 pounds per acre, although even dust distribution was difficult to obtain. The insects for the tests were largely swept from alfalfa, and were treated within 24 hours. For each test, 10 insects were used. The results are discussed under the headings of the various insects.

Adults of Diabrotica 11-punctata

Evidently, diabrotica beetles are very sensitive to DDT in any form. When they were placed on dusted or sprayed broccoli plants in cages, their immediate reaction to DDT was less noticeable than when they were sprayed or dusted directly. In most cases, however, the time required for a 100 per cent kill was the same whether the insects were directly treated or were placed on treated foliage. From the standpoint of eventual mortality there was no consistent difference between the different percentages of DDT in the oils for the range 0.3 to 3.6 per cent. There was, however, a greater carryover effect where the higher percentages of DDT were applied to the plants. The 3 per cent dust was superior to the 1 per cent dust (table 18).

TABLE 18

Summary of Laboratory Studies on the Effect of DDT on Diabrotica Beetles, Using Ten Insects for Each Test

To what applied	Days between treatment and caging of insects	Days to first dead after caging	Days to 100 per cent mortality
0.3 per cent DDT by weight in a vapo-spray			
Broccoli	0	2	2
Insects(direct)	...	1	2
0.6 per cent DDT by weight in a vapo-spray			
Broccoli	0	1	1
Insects(direct)	...	2	3
1.2 per cent DDT by weight in a vapo-spray			
Broccoli	0	2	7
Broccoli	2	2	6
Alfalfa	2	5	7
Alfalfa	35	3	...
Insects(direct)	...	2	3
2.4 per cent DDT by weight in a vapo-spray			
Broccoli	0	1	11
Broccoli	2	2	6
Broccoli	5	1	3
Broccoli	35	2	...
Alfalfa	2	2	3
Alfalfa	6	1	3
Alfalfa	35	3	...
Insects(direct)	...	1	5
3.6 per cent DDT by weight in a vapo-spray			
Broccoli	0	1	5
Broccoli	2	1	4
Alfalfa	2	2	3
Alfalfa	6	1	2
Alfalfa	40	1	5
Insects (direct)	...	1	7
1.0 per cent DDT dust			
Broccoli	0	2	4
Broccoli	2	5	7
Insects (direct)	...	2	10
3.0 per cent DDT dust			
Broccoli	0	1	5
Broccoli	2	1	7
Broccoli	5	1	2
Insects	...	1	2

[30] Prepared by W. H. Lange, Jr., Junior Entomologist in the Experiment Station.

[31] The help of Frank Herbert in conducting these experiments is gratefully acknowledged.

The beetles reacted to the DDT within an hour, first by nervousness, then by loss of equilibrium. After another hour, a few were on the bottom of the cages on their backs with their legs waving in the air. Several days were usually required for a final kill, although there was no further evidence of any feeding and although no beetles recovered. Spray on alfalfa plants treated on January 20 killed, within 5 days, 100 per cent of the pests introduced on March 11. A similar effect was noticed with the 2.4 and 1.2 per cent vapors, although the 1.2 per cent strength killed only 20 per cent of the beetles introduced March 6. Table 18 summarizes the results with diabrotica beetles.

Adult Lygus Bugs

Vapo-sprays with 1.2, 2.4, and 3.6 per cent DDT were effective when applied to plants on which lygus bugs were subsequently placed or when applied directly on the insects. Little difference in the time required to kill all the bugs was found among the different percentages used. Alfalfa plants sprayed with the 3.6 per cent strength on January 20, and introduced January 31, killed 100 per cent of the bugs within 4 days. When the DDT materials were applied directly to lygus bugs, the insects showed an immediate effect. At first they appeared to lose some locomotive power and would climb repeatedly up the sides of the cages, only to fall down. Later they lost all power of locomotion and remained on their backs, kicking their feet, until death ensued. Table 19 presents the results.

TABLE 19

Comparative Effect of Various Concentrations of DDT on Lygus Bugs, Applied as Vapo-sprays Directly on the Bugs, or Applied on Plants, the Insects Being Introduced Immediately after the Application*

Per cent of DDT by weight in a vapo-spray	Plants or insects to which applied	Days to first dead after caging	Days to 100 per cent mortality
1.2	Broccoli	1	8
1.2	Insects (direct)	1	7
2.4	Broccoli	3	8
2.4	Insects (direct)	2	5
3.6	Broccoli	1	8
3.6	Alfalfa	2	4
3.6	Insects (direct)	1	8

*In each test 10 lygus bugs were used.

Vegetable Weevil Larvae

In these tests the materials were applied directly to the insects or to 1/4-inch carrot sections on which larvae were later placed. The vapo-spray materials gave a more rapid kill than the dusts, although the 3 per cent dust was comparable with the 1.2 per cent oil mixture. Weevil larvae did not die rapidly, but remained in a stupor for a week or more; the 1 per cent dust, for example, kept them in this state 6 to 9 days. They fed vigorously on the dusted or sprayed carrot sections at first, but then stopped feeding and remained inactive until death. When dead they were internally discolored. Table 20 shows the results.

Potato Tuber Moth

Larvae of the potato tuber moth displayed a violent reaction to DDT materials applied directly to them. Violent wriggling during the first 3 hours was followed later by spasmodic jerks and finally by death. Larvae placed on potato sections did not show much effect at first, but all died in a few days. The larvae reacted faster to vapo-spray materials than to 3 per cent DDT dust. Adult moths when dusted or sprayed with the DDT combinations displayed an immediate loss of locomotion and flight, and died within 24 hours. Table 21 summarizes the results of these experiments.

TABLE 20

Comparative Effect of DDT on Mature Vegetable Weevil Larvae Where the Materials Were Applied Either Directly to the Insects or to Small Sections of Carrots on which Larvae Were Placed

Per cent of DDT by weight, in treatment	To what applied	Days to first dead	Days to 100 per cent mortality
Vapo-sprays			
1.2	Larvae (direct)	2	3
1.2	Carrots	2	3
2.4	Larvae (direct)	1	3
2.4	Carrots	1	3
Dusts			
1.0	Larvae (direct)	2	9
1.0	Carrots	2	6
3.0	Larvae (direct)	3	4
3.0	Carrots	1	3

TABLE 21

Comparative Effect of DDT on the Potato Tuber Moth Where the Materials Were Applied Directly to the Adults or Larvae or to Sections of Potatoes Which Were Immediately Infested with Larvae

Per cent of DDT by weight, in treatment	To what applied	Days to first dead	Days to 100 per cent mortality
Vapo-sprays			
0.6	Larvae (direct)	1	2
0.6	Adults (direct)	1	1
0.6	Potato	1	2
1.2	Larvae (direct)	1	3
1.2	Adults (direct)	1	1
1.2	Potato	1	5
Dusts			
3.0	Larvae (direct)	1	3
3.0	Adults (direct)	1	2
3.0	Potato	1	5

CONTROLLING CODLING MOTH ON WALNUTS WITH DDT[32]

In the work with codling moth, Carpocapsa pomonella (L.), the DDT plots were at Linden, in San Joaquin County; and the study was conducted on the Payne variety of walnut. One and two spray applications were compared.

The composition of the first spray was as follows: 5 pounds of 20 per cent DDT wettable powder (A20) to 100 gallons of water. The second spray had the following composition: 5 pounds of 20 per cent DDT powder (AK20) and 4 ounces of blood albumin, to 100 gallons of water.

For the first spray the DDT was slowly added to a tank half full of water. For the second, the DDT and blood albumin were thoroughly mixed, then slurried; and the mixture was slowly added to a half-full tank. The sprays were applied with a Bean spray rig through a Meyer gun at a pressure of about 500 pounds. From 30 to 35 gallons was used per tree for the first spray; 20 to 35 gallons for the second.

The first spray was applied on May 9. No infested nuts were observed at this time, though an examination of 200 nuts from check trees revealed one small caterpillar on the outside of a nut. With the exception of the walnut aphid, nearly all insect life appeared to have been knocked from the trees shortly after the spray was applied. On the ground there were many insects, including ladybird and other beetles, parasites, flies, a few caterpillars, and adult codling moths. There were also spiders. Most of these organisms were nearly dead, or incapacitated and kicking. The adult codling moths seemed to be the least affected of the insects. On May 10, the day after the trees were sprayed, very few aphids were found alive on the trees, and there were many dead on the ground. The aphid population trends as probably affected by DDT are discussed in the section "Effect of DDT on the Walnut Aphid."

In the growing season, 11 thorough tree examinations were made to determine the degree of codling moth infestation. The surveys were generally made at intervals of about 2 weeks. The DDT-sprayed trees remained practically free of infested nuts. The check trees became heavily infested; the infestation in them built up rapidly and by the end of May was about 30 per cent. On May 29 the DDT-sprayed trees were nearly free of insects. Three small codling moth larvae were observed on nuts. These moved slowly and did not appear normal. On June 7, numerous eggs were observed, and 3 newly hatched larvae. The latter, though apparently normal, showed no signs of trying to enter nuts. On June 26, 480 nuts were examined. Two of these were found infested. The larvae had not penetrated the normal husks, but gained entry through injuries. Many hatched eggs were observed, and there was some evidence of larval activity; but most of the larvae, at least, appeared to have died without being able to penetrate the husks. Of 235 dropped nuts collected, 26 were infested. Possibly some of these nuts had been infested before the spray was applied on May 9. In 13 (or 5.5 per cent) of the nuts, entry was made through the blossom end; and in a like number, entry was through the side or the stem end. In the latter cases, all entries were through blighted or otherwise injured areas.

Half of the treated trees were sprayed for a second time on June 26 because the first spray appeared to be losing its effectiveness. As with the first spray, most insects in the trees were dislodged.

According to all the following surveys, trees that were sprayed twice remained nearly free of infested nuts. In trees sprayed only once, a fair infestation appeared likely to set in. On July 24, 2.08 per cent of the nuts (as determined by tree surveys) were found infested, and some of the larvae had penetrated through uninjured husks. Most of these larvae, however, apparently died before penetrating far, for the later surveys showed a marked drop in the percentage of nuts infested. In the harvested crop only 0.9 of 1 per cent of the nuts were infested where the trees were sprayed once, and none were found where the trees received two applications of DDT. Furthermore, two thirds of the nuts infested, where the one spray was applied, would have been classed as culls for other reasons. The degree of infestation of the harvested crop from the check trees was 18.63 per cent.

Results of DDT residue determinations on walnuts, made late in August, are given in the section on residues. As would be expected, the nuts sprayed twice showed a much higher deposit than those that had only one spray, applied when they were very small.

Conclusions

According to the results of this experiment, DDT is highly effective against the codling moth. One spray applied May 9, when the walnuts were still extremely small, produced exceptionally good control. In July, when the second brood of moths was making its appearance, the spray seemed unlikely to give adequate protection. Although some larvae did penetrate the husks, most of these died without doing any damage. The second brood during the season was smaller than usual. Not until after further study will it be possible to conclude that a single early spray will effectively protect the walnut crop from the first and second broods of codling moths. Trees sprayed May 9 and again on June 26 gave as perfect control as could be expected. Although the results are very promising, much more work is needed before DDT can be safely recommended for commercial use.

[32] Prepared by A. E. Michelbacher, Assistant Entomologist in the Experiment Station; Clark H. Swanson, Assistant in Agricultural Extension; and Gordon L. Smith, Associate in the Experiment Station.

EFFECT OF DDT ON THE WALNUT APHID[33]

The effect of DDT on the walnut aphid, Chromaphis juglandicola (Kalt.), was observed during the use of this material against codling moth on walnuts at Linden, California.

A single application of spray on May 9 was compared with two applications, one on May 9 and the second on June 26. The composition of the sprays and other data pertaining to treatment are given in the section "Controlling Codling Moth on Walnuts with DDT."

The walnut aphid was very abundant at the time of the May 9 spraying. Nearly all insect life except the walnut aphid was knocked out of the trees shortly after the spray was applied. On May 10, the day after treatment, many dead aphids were on the ground, and almost none could be seen on the trees. On May 18 very few aphids and no ladybird beetles appeared to be present.

Twenty days after treatment no immature aphids could be found. The few winged forms noted are believed to have flown in from the surrounding heavily infested trees. One or two Hippodamia adults were observed, as was a green lacewing adult. Eggs of the latter species were also noted. By June 7 some aphid reproduction had occurred, and green lacewing eggs were easy to find. At this time the aphid population became so great that the entire orchard where the plots were located was dusted with a nicotine dust. The resulting kill was exceptionally good.

On June 26, very little aphid reproduction was evident on the DDT-sprayed trees. Half these trees were treated a second time. Some few ladybird beetles were knocked off; but since there were not many, conditions were apparently just becoming favorable for them to exist in the trees. By July 10 there was some increase in aphids where the trees had received but one spray; but the number present was far from being of serious proportions. Where two sprays were applied, practically no aphids were evident. On July 24, the trees sprayed once showed a marked build-up in aphid population, and numerous ladybird beetle eggs were observed. Where two sprays had been applied, no aphids, or very few, were apparent.

By August 8 the trees sprayed once with DDT showed considerable aphid injury in comparison with the trees sprayed twice or the surrounding unsprayed trees. The foliage was yellowish, and there were more drying leaves. On these trees there were many ladybird beetles as well as some syrphid fly larvae. Where two sprays had been applied, a very large aphid population had developed. No ladybird beetle larvae were noted, though a few adult Hippodamia and a few clusters of freshly laid ladybird-beetle eggs were seen. The aphid infestation in the orchard where the plots were located had reached a stage where much damage was being done. The aphid population, though very large, was considerably less than on the trees sprayed with DDT. The number of aphids per leaflet was compared. The leaflet selected for examination was next to the terminal one; and leaflets were collected at random around the skirt of the trees. The number of leaflets examined and the average number of aphids found per leaflet were as follows:

Treatment	Number of leaflets examined	Average number of aphids per leaflet
Unsprayed	78	81
Sprayed once with DDT .	36	129
Sprayed twice with DDT.	36	239

Because of the severe aphid damage the orchard was treated with a nicotine dust. The result was a satisfactory kill throughout the orchard, including the DDT-treated plots. Without the nicotine treatment, the DDT-treated trees would probably have been seriously defoliated. The nicotine dust was applied just in time to save the trees sprayed twice with DDT; if the extremely large aphid population had not been destroyed, marked injury would have occurred within a few days. As a result, the trees sprayed only once were more severely injured than those sprayed twice. In addition, they showed fewer aphids, probably because many predators were present whereas in the two-spray treatment the predators were just becoming established. The delayed build-up in the aphid population with the two sprays was undoubtedly the result of the aphids' being controlled for a longer period with this treatment.

On August 24 there were very few aphids on all trees sprayed with DDT. The trees of both treatments appeared to be lighter green than the surrounding unsprayed trees. At harvest, the DDT-treated trees were found to have been more severely injured by aphids than the others. The extent of the damage was as follows:

1. Most severely injured: trees sprayed once with DDT.
2. Less severely injured: trees sprayed twice with DDT.
3. Least severely injured: unsprayed surrounding trees.

Conclusions

In the work on walnuts at Linden, DDT was effective in killing the walnut aphid. It also killed the predators and probably the parasites. Eventually, however, serious infestations of the pest developed. According to observations, this trouble could be explained by the fact that DDT remains effective against the predators and parasites longer than against the aphid itself. Thus the aphid becomes established and builds up a large population before being subjected to its natural enemies. The results of this investigation indicate that more work is needed before any recommendations can be made for the use of DDT as an insecticide on walnuts.

[33]Prepared by A. E. Michelbacher, Assistant Entomologist in the Experiment Station; Clark H. Swanson, Assistant in Agricultural Extension; and Gordon L. Smith, Associate in the Experiment Station.

STUDIES ON THE POSSIBLE EFFECTS OF DDT ON THE GROWTH OF RICE AND BARLEY[34]

As a result of studies on mosquito control in irrigated agricultural areas, it became essential to determine the possible secondary effects of DDT on crop production in the districts affected. Controlled greenhouse experiments were performed to elucidate the possible effects of this chemical--first, on the germination of seed; second, on the soil microflora; third, on the over-all growth of plants under conditions similar to those suggested by the United States Public Health Service for controlling the mosquitoes in areas where rice is normally grown. This is a brief summary of the studies; a more complete report is being prepared for publication elsewhere.

Rice seed was germinated in aerated suspensions of DDT in water. The percentage germination was not materially affected over a wide range of quantities dispersed in suspensions of 0.1 to 100.0 p.p.m. of DDT. The viability of the seed was not markedly impaired by concentrations soluble in aqueous media, nor by excess of the chemical in suspension in intimate contact with the germinating organism.

In another experiment,[35] water suspensions containing 10 and 100 p.p.m. of DDT were incorporated with appropriate media; and the subsequent development of a mixture of microorganisms common to soils was observed therein. Growth was not significantly affected by the presence of this insecticide.

The third phase of this investigation embodied the possible effects of soil treatment on the growth of rice and barley. Two situations were of interest: first, a pretreatment of the soil equivalent to an annual DDT irrigation flooding of rice lands, followed by the growth of either rice or barley in 18 kilos (air-dry) of Yolo silty loam contained in metal tanks, the rice soils being flooded with water at seeding time or later; second, a concurrent DDT irrigation of soil by flooding (to a depth of 4 inches) and by growth of rice. Soil, pretreated with the DDT-oil emulsion, as recommended by the Malaria Control Division of the Public Health Service,[36] supported subsequent growth of either rice or barley under the experimental conditions, comparable with that produced on similar untreated soil. Under the limited conditions of these controlled experiments, germination and vegetative development of rice were not significantly impaired when the concurrently applied irrigation water contained the insecticide-oil emulsion. Plant growth, including grain production and maturation, was satisfactory when soil was either previously or simultaneously treated with the mixture lethal to mosquito larvae. In one series, grain production was reduced, but the difference from the control was not highly significant. Flooding of the soil with water, alone or in conjunction with the insecticide mixture, at or before the time of seeding, as compared with later flooding, may reduce the percentage germination. Experimental differences, however, were statistically not highly significant.

From the standpoint of agricultural soil economy, the recommendations for destroying the mosquito larvae are probably not objectionable, at least for a limited number of applications.

[34]Prepared by T. C. Broyer, Assistant Plant Physiologist in the Experiment Station.

[35]This study was carried on by H. A. Barker, Assistant Professor of Soil Microbiology and Assistant Soil Microbiologist in the Experiment Station.

[36]Five per cent DDT and 0.5 per cent of appropriate emulsifier in no. 2 Diesel fuel oil, applied at the rate of 1 part to 20 million parts of water.

ANALYSES FOR DEPOSITS AND RESIDUES OF DDT IN 1944[37]

A quantitative analysis for DDT may be based upon a certain fact--namely, that when the compound is warmed with alcoholic alkali, one molecule of hydrogen chloride is split out. This liberated chloride may then be determined by any quantitative method such as titration with standard silver nitrate solution, chromate being used as indicator. To exclude inorganic chloride, the sample suspected of containing DDT is extracted with benzene, in which DDT is readily soluble but inorganic chloride is not.

In the present work, the procedure was as follows. The sample was placed in a jar with benzene and gently shaken for about 1/2 minute. The benzene was then poured through a cotton filter in a funnel to remove dirt and other foreign matter, and another portion of benzene was added to the sample. A third portion was used for rinsing the sample and funnel; and the total volume of benzene was brought to a definite volume, usually 250 or 500 cc. An aliquot portion, usually 100 cc, was placed in a vacuum distilling flask resting on an asbestos screen, and the benzene removed by very gentle heating. Without removing the residue from the flask, 10 cc of 1 normal alcoholic sodium hydroxide was added; and the contents were refluxed gently for 20 minutes. The solution was then cooled, and the condenser was rinsed by introducing 10 cc of distilled water from the top. A drop of phenolphthalein solution was then added to the flask, and just enough 1 normal nitric acid was put in to discharge the red color. Next, 1 cc of 1 per cent sodium chromate solution was added, and the total volume brought to about 30 cc. The solution was then titrated with standard 0.01 normal silver nitrate solution to the first change of color due to formation of a minute amount of the reddish silver chromate. This end point is definite ex-

[37]Prepared by W. M. Hoskins, Professor of Entomology and Entomologist in the Experiment Station.

cept when the solution is contaminated with dark or otherwise strongly colored substances from the sample. Such difficulty was seldom encountered, and filtering after the digestion with alkali was an effective remedy for it.

The accuracy of the procedure was checked at intervals by adding known amounts of pure DDT to field samples not previously exposed to DDT. Recovery was satisfactory: for example, the addition of 8.8 and 11.8 mg of DDT to pear peelings resulted in recovery of 8.7 and 11.7 mg; and from 7.0, 9.5, and 10.2 mg added to pear meat, 7.4, 9.3, and 10.1 mg, respectively, were recovered. Allowance was made, of course, for chloride in the reagents, which amounted to 0.16 mg, chiefly in the alkali. When samples of the various plant materials from untreated plots were analyzed, no material was found that yielded chloride and hence might be mistaken for DDT.

Samples of plant materials treated with DDT sprays or dusts were obtained from the field and analyzed by the procedures described above.

Residues on Alfalfa

An alfalfa field was treated with 3 per cent DDT dust (A3) at the rate of 28 pounds per acre on July 26 and again on August 12. A sample was taken on September 8 and found to contain 29 p.p.m. DDT, calculated on fresh weight of the alfalfa.

Residues on Bartlett Pears

Analysis was made for DDT deposit residues on Bartlett pears that had been sprayed with 5 pounds of 20 per cent wettable DDT powder (A20) per 100 gallons of water. The fruit was picked August 7, and analyzed August 22 to 26, inclusive, with the following results:

Dates sprayed	DDT, p.p.m.
May 5 and 22	0.5
May 5 and June 14	2.7
May 5 and July 6	2.1
May 5 and 22, June 14, and July 6. .	3.7

Likewise, analysis was made of deposit residues from spraying with 2-1/2 quarts of 20 per cent DDT in emulsible oil base (SH20) per 100 gallons of water. Results were as follows:

Dates sprayed	DDT, p.p.m.
May 5 and 22	1.7
May 5 and June 14	2.3
May 5 and July 6	3.6
May 5 and 22, June 14, and July 6. .	6.1

Residues on Walnuts

Walnuts of the Payne variety were analyzed for DDT deposit residue. A spray containing 5 pounds of 20 per cent DDT wettable powder (A20) was applied on May 9. Samples were picked July 10 and analyzed August 27. The residue was 13 micrograms DDT per square inch of walnut surface.

On a portion of the plot a second spray was applied June 26. This consisted of 5 pounds of 20 per cent DDT powder (AK20), plus 4 ounces of blood albumin, per 100 gallons of water. Samples taken at the same time as described above gave a residue of 43 micrograms of DDT per square inch of walnut surface.

The results of analysis of other materials are shown in tables 22, 23, and 24.

TABLE 22

Deposit Residues of DDT on Peas, Resulting from Two Applications of Vapo-spray at the Rate of 5 Gallons per Acre, on August 29 and September 2

Composition of spray*	Portion of plant analyzed †	DDT in parts per million
0.3 per cent DDT by weight in oil	Pods	39
0.6 per cent DDT by weight in oil	Pods	54
1.2 per cent DDT by weight in oil	Pods	76
2.4 per cent DDT by weight in oil	Pods	93
	Kernels	Not over 0.5

*The oil-base carrier used was 30 per cent kerosene and 70 per cent mineral seal oil (92 U.R.).

†All samples were picked on September 26 and analyzed October 2.

TABLE 23

Deposit Residues on Olive Foliage and Fruit

Composition of spray per 100 gallons	Date sprayed	Portion of plant analyzed	Date sample picked	Date analyzed	DDT in micrograms per square inch	DDT in parts per million
Mission variety						
1 per cent by volume of light medium oil plus 1/2 per cent by volume of 20 per cent DDT in oil (SH20)	July 27	Leaves	Aug. 15	Aug. 29	47	...
1-2/3 per cent by volume of light medium oil containing 40 grams DDT (GNB-A) per liter	July 18	Leaves	Sept. 7	Sept. 22	21	...
	July 18	Olives	Sept. 5	Sept. 23	...	30
	July 15	Olives	Sept. 5	Sept. 25	...	26
2 per cent by volume of mineral seal oil containing 40 grams DDT (GNB-A) per liter.	July 18	Leaves	Sept. 7	Sept. 28	40	...
	July 18	Olives	Sept. 7	Sept. 26	...	23
	July 18	Olives	Sept. 7	Sept. 30	...	27
1/4 per cent by volume of heavy medium oil, plus 4 pounds of 20 per cent DDT powder (AK20)	July 17	Olives	Aug. 9	Sept. 27	...	33
Manzanillo variety						
3 per cent by volume of kerosene containing 60 grams DDT (GNB-A) per liter, plus 1 ounce of dioctyl ester of sodium sulfo succinate emulsifier	Sept.11	Leaves	Sept. 12	Sept. 23	97	...
	Sept.11	Olives	Sept. 12	Sept. 20	...	71

TABLE 24

DDT Deposits and Residues on Foliage, on Small Green Fruit, and on Mature Fruit of Tomatoes*

Date sprays were applied	Date samples were taken	Portion of plant analyzed	DDT in micrograms per square inch	DDT in parts per million
Aug. 21 and Sept. 5	Sept. 10	Leaves from over whole plants.	86	...
		Leaves from top of plants	58	...
		Leaves from bottom of plants	53	...
Aug. 21 and Sept. 5 and 16	Sept. 16	Leaves from over whole plants	240	...
		Leaves from top of plants	260	...
		Leaves from bottom of plants	157	...
Aug. 21 and Sept. 5 and 16	Sept. 30	Leaves from top third of plants . . .	83	...
		Leaves from center third of plants . .	113	...
		Leaves from bottom third of plants . .	138	...
Aug. 21 and Sept. 5, 16, and 30	Sept. 30	Leaves from top third of plants . . .	69	...
		Leaves from center third of plants . .	103	...
		Leaves from bottom third of plants . .	210	...
Aug. 21 and Sept. 5, 16, and 30	Sept. 30	Small green tomatoes, about 1/2 inch in diameter	...	8
Aug. 21 and Sept. 5, 16, and 30	Nov. 20	Ripe tomatoes, average weight 50 grams	...	Not over 0.5

*Composition of spray per 100 gallons used August 21 and on September 5 and 16 contained 5 pounds of 20 per cent DDT powder (AK20) and 6 ounces of blood albumin. Spray used September 30 contained 1 pound DDT (GNB-A) and 6 ounces of blood albumin.

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